Multiphysics Analysis of a Burning Candle

These solution methodologies have been applied to a range of applications to predict the temperature distribution associated with a burning flame.

ALTASIM TECHNOLOGIES, COLUMBUS, OHIO

Over 150 years ago, Faraday provided the first comprehensive scientific study on the physics of burning candles. Complex combustion driven by the rate at which gases diffuse through each other produces a highly non-linear temperature profile through the flame. With local temperatures in the flame exceeding 1400 °C, heat transfer includes radiation, conduction, and convection components. The low melting point of the candle wax leads to a local phase change close to the wick that allows mass transport via capillary flow prior to combustion in the flame.

Any attempt to model candle operation accurately from the fundamental physics in its entirety would be an immense undertaking and require resources that are unrealistic. AltaSim Technologies combined COMSOL Multiphysics V 3.5 analysis software with generalized strategies to develop computational models of burning candles. These models focus on analyzing the heat transfer and fluid flow during steady state candle burning. Analysis of the heat transfer combines conduction, convection, and radiation. Radiation from the candle flame was included in the models by defining a radiating surface of the flame that is non-locally coupled to the radiating gas volume. The radiation emanating from this surface is determined by the temperature distribution within the flame, and the gas within the flame is accordingly cooled due to the radiation. To reduce computational requirements, the complicated dynamic behavior of the plume was accounted for using artificial diffusion to generate a time-averaged approximation. Heat transfer within the liquid wax was modeled using an anisotropic thermal conductivity to account for convection in the horizontal direction.

Figure 1 shows the predictions of the velocity flow field using this approach for a half-burned, three-wick candle, clearly demonstrating spreading of the flow away from the flame. Predicted temperature distributions within the wax (Figure 2) and in the candle container compare favorably with experimental measurements. These results can be used to predict the location of the solid/liquid interface during burning and temperature distributions in the candle and the surrounding environment.

These solution methodologies have been applied to a range of applications to predict the temperature distribution associated with a burning flame. The temperature and flow patterns are considerably influenced by the spatial location of the flame within a container, the container geometry, and the height of the candle within the container. Convective flow and heat transfer outside the immediate vicinity of the candle flame can predict the transfer of heat to nearby objects. ■

ACKNOWLEDGEMENTS

This work was performed by L.T. Gritter, S.P. Yushanov, J.S. Crompton, and K.C. Koppenhoefer of AltaSim Technologies using COMSOL Multiphysics. For more information, visit **http://info.hotims.com/28057-152**.

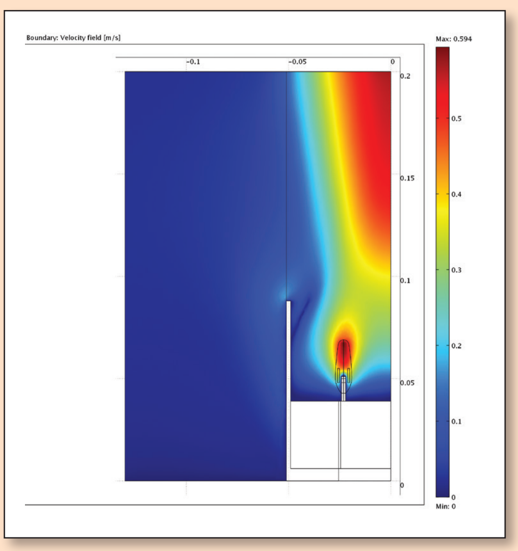

Figure 1. Velocity Flow Field for a burning candle at half-container height.

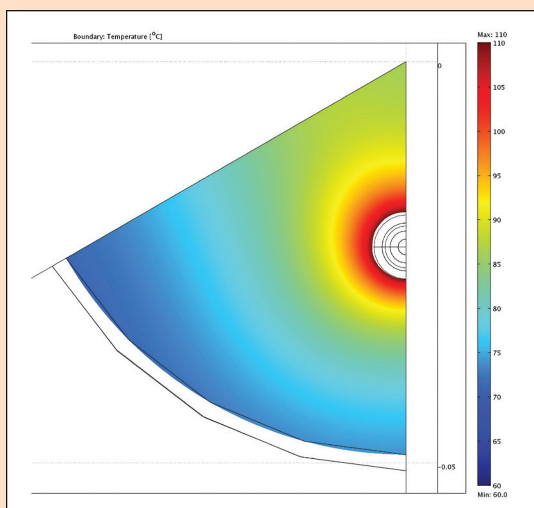

Figure 2. Surface Temperature of Wax during burning, 1/6th symmetric model.