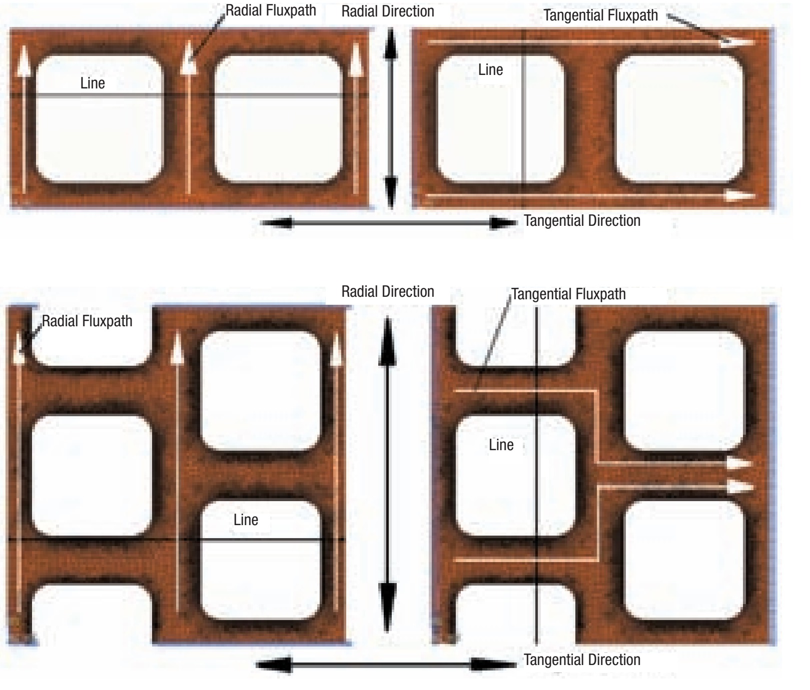
Making Sure Wood Gets **Heat Treated** with Respect

The ANSYS Parametric Design Language helps establish the thermal conductivity of wood and composites to enable more effective heat treatment processes.

By John Krouse, ANSYS Advantage

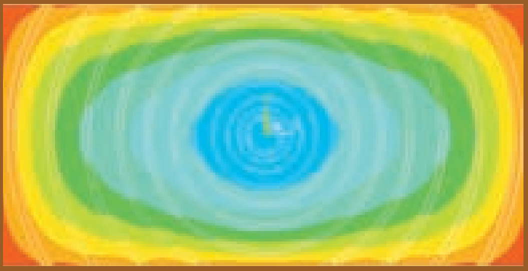
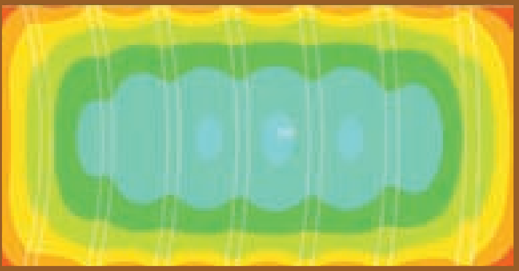
Established in 1910 by the U.S. Department of Agriculture Forests Service, the Forest Products Laboratory serves the public as the nation's leading wood research institute and is internationally recognized as an unbiased technical authority on wood science and utilization. The lab is the public side of the public-private partnership needed to create technology for the long-term sustainability of forests. According to a recent study, tax dollar investment in forest products research generates as much as a 300 percent return to society.

One particular area of research at the lab is focused on more precisely establishing the thermal conductivity of wood. This property is of critical importance in the drying process since too little heat treatment results in retained moisture and long drying times while too much treatment may damage the structure of the wood. Conventional models developed more than 50 years ago serve as a rough guideline for calculating an average thermal conductivity for certain types of wood. However, because of the inherent inaccuracies of this approach, lumber mills and wood processing companies must perform trial-and-error tests to determine proper temperatures and drying times — a costly, time-consuming process that often results in high scrap rates.



Micro-level analysis models represent different wood cell orientations, with softwood cells aligning in straight rows (top) and hardwoods having cells offset by perhaps 50 percent (bottom).

The heat transfer coefficients of wood depend on many variables, including ring density, the age of the tree, initial moisture content and orientation of the cells. Porosity can range from 70 to 90 percent in earlywood and from 10 to 30 percent in latewood growth. Moreover, in softwood, the cells tend to align in straight rows in the radial direction and are offset in the tangential direction. Compounding the difficulty, these characteristics usually are not uniform across all sections of the same tree, since wood structure can be affected by seasonal weather differences. Also, the ring density (and

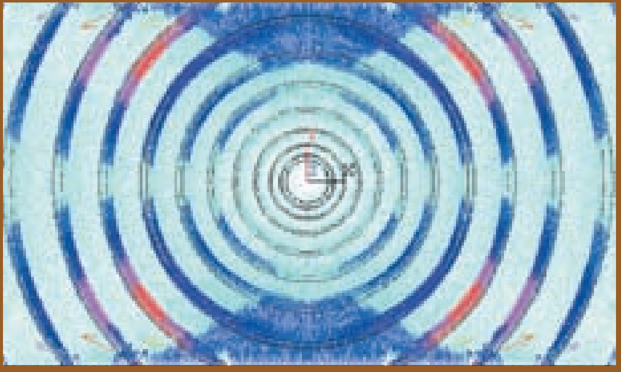
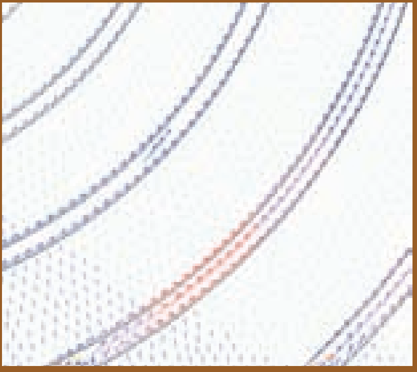
Contour plots indicate the temperature distribution at two locations with different ring structures at the same point in time in the same wood board.

thus heat transfer) in small versus large-diameter trees varies widely depending on the growth rates for different conditions, which are governed by the surrounding vegetation and climate fluctuations.

On the micro (cellular) level, models programmed using ANSYS Parametric Design Language (APDL) were developed to simulate the structural variation of cell porosity and alignment in determining the effective heat transfer coefficients. For the macro level, boards cut from seven different locations in a typical log were modeled to examine the effects of wood structure on the transient heat transfer process using the thermal conductivity values obtained from the micro-level analyses. Dozens of simulations were required to determine the heat transfer rates for a wide range of wood geometries and structural conditions. APDL performed repetitive analyses in which new values of various parameters could be entered and analyzed without manually rebuilding multiple simulation models.

The FEA simulations showed the significant effects of cell alignment, cell density, ring width and ring orientation on the thermal conductivity of wood. The study concluded that the porosity of wood as well as the growth rate of the tree play major roles in determining the effective thermal conductivities, which can be fitted to equations or stored in a look-up table for further use in macro wood models. The results also showed that heat transfer in a piece of wood is affected significantly by ring density and orientation, and quarter-sawn boards have higher heat transfer rates than flat-sawn boards due to the shorter pathway through latewood cells. This insight will enable more effective wood heat treating processes and help better utilize this critical natural resource.

According to John Hunt from the USDA Forest Products Laboratory, "The finite element models allowed engineers to examine the fundamental thermal conductivity differences for radial and tangential heat transfer at the micro level, and also to estimate the transient heat transfer effects at the macro level in a board of wood. A parametric method enabled numerous simulations to be run efficiently, providing a broad range of data needed to determine the heat transfer coefficients. Such an approach in studying heat transfer issues in wood has many practical applications that include optimizing drying schedules for different board cuts, determining heat treatment times to kill insects and determining heat curing times for solid wood as well as composites. In this respect, FEA software is a valuable tool to explore and review the fundamental laws of science." ■

Vector plots of heat flux showed high and low thermal transfer in earlywood and latewood due to different cell densities in these regions. Heat flux vectors (left) are enlarged to show the detail near the rings (right).