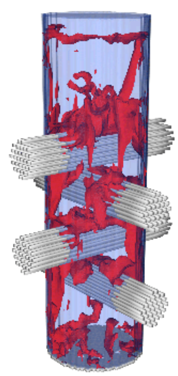
3D visualization helps researchers understand key processes in pulp and paper manufacturing

by Michelle Perkins

The National Energy Technology Laboratory (NETL) and Pittsburgh Supercomputing Center (PSC) are using advanced CFD visualization to better understand the complex hydrodynamics used in pulp and paper manufacturing. Researchers believe their work can lead to greater energy efficiency, safer work environments, and better environmental controls.

Pulp and paper production has traditionally been one of the most energy-intensive processes of any type of manufacturing. Over the past 20 years, these processes have improved significantly by reusing black liquor, the residue that results when fiber is extracted from wood. To achieve this, the black liquor is burned in boilers to recover the pulping chemicals. Yet even with these changes, researchers recognized that gasification of the black liquor could further improve the efficiency of the manufacturing process.

Georgia Pacific replaced existing boilers with a fluidized-bed system that can combust and gasify black liquor, a mixture rich in carbon, to recover chemicals and generate steam and energy. NETL and PSC researchers are using CFD simulations to predict hydrodynamics within this gasification process, which they hope will lead to design improvements that can provide better energy efficiency, eliminate the danger of boiler explosions, and reduce toxic air emissions.



EnSight 3D visualizations are helping researchers better understand and improve black liquor gasification used in pulp and paper manufacturing.

Predicting bubble behavior

The challenge for NETL and PSC researchers was simulating the complex interactions within Georgia Pacific's fluidized-bed system. Four perpendicular tube bundles supply heat to the bed. Fluidization gas enters through the bottom of the bed and black liquor is injected into the lower region. The black liquor coats an inert bed material that combusts and gasifies as it travels upward, forming bubbles that flow through and around the tube bundles. The transient behavior of these bubbles determines the mix of gas versus solids in the flow through the bed, with the goal of keeping the bed well mixed and thermally homogeneous. To model such a complex system, it is critical to predict bubble behavior.

NETL used in-house software called MFIX (Multiphase Flow with Interphase eXchanges) to simulate the gasification process. MFIX can predict hydrodynamic behavior, track gas and solid species, and determine temperature distribution throughout the fluidized-bed system. LeMieux, PSC's terascale computing system, was used to calculate the very large datasets generated by the simulations, and CEI's EnSight software was used to visualize the results.

Lemieux comprises 750 Compaq Alphaserver ES45 nodes and two separate front-end nodes. Each computational node contains four 1-GHz Alpha EV6.8CB processors and runs the Tru64 UNIX operating system. A Quadrics interconnection network connects the nodes.

“LeMieux enables us to run multiple jobs simultaneously to vary the particle size and gas flow rates,” says Chris Guenther, NETL research scientist. “PSC accommodates the large datasets with its FAR storage system. The high-speed fiber link between PSC and NETL allows us to bring these datasets back to NETL in minutes.”

EnSight was selected for the project because it is designed to handle large, complex data sets such as those required for black liquor gasification visualization. The software enabled researchers to visualize areas of low solids concentrations (bubbles) throughout the bed, and see how the bubbles interact with obstructions inside the bed.

One of the critical questions in the research was whether the bubbles travel through the heat exchangers, or by-pass them and cling to the walls as they travel up through the bed. EnSight clearly showed (with the areas of red in the image) that the bubbles travel up through the heat exchangers.

Easy-to-understand 3D visualizations

The 3D visualizations generated in EnSight displayed transient phenomena for single-field variables such as void fraction, velocities, pressure, temperature, and species concentrations. Each of these field variables could generate a file size of about 1.5 gigabytes.

“EnSight not only handles these large data sets, but can also navigate in time very efficiently through the data,” says Guenther.

Without 3D software that can handle very large, transient data sets, researchers would have had to resort to using 2D slices to visualize the data.

“This is okay,” says Guenther, “but you miss a lot of the 3D behavior that is inherent to these simulations. In addition, when it comes to showing your results to an audience that is not savvy in CFD, being able to show a transient 3D view of what is happening inside the bed is extremely helpful, and much easier for them to understand. We could have come to the same conclusions in our research without EnSight, but it would have taken considerably longer.”

Projects such as this one funded through the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy are expected to have far-reaching effects on the nation’s economy and ecological efforts. The ability to visualize what was previously impossible to see will help the country’s pulp and paper producers become more competitive, cost-effective, and environmentally friendly.

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Michelle Perkins is a freelance writer who covers the computer graphics, IT and electronics industries.

CEI Press contact: Amanda Baley, 919-363-0883