Computation Helps Boost Energy Efficiency in Paper Processing

Under the High-Performance Computing for Manufacturing (HPC4Mfg) Program, researchers are developing detailed computer models to optimize the paper-making process.

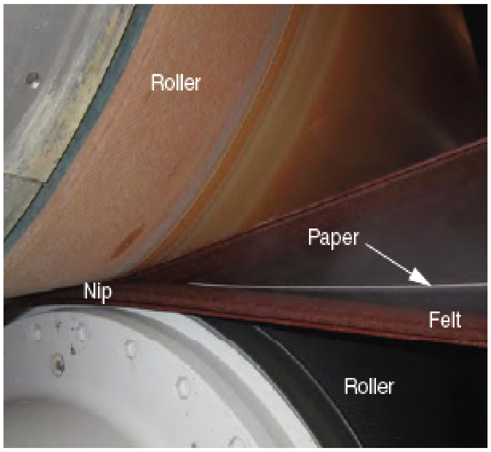
Industry Need for More Energy-Efficient Processes

According to the U.S. Energy Information Administration, paper manufacturing is the third-largest energy consuming industry in the United States, ranking only behind petroleum-refining and chemical manufacturing. To mitigate the paper industry's energy burden, the Agenda 2020 Technology Alliance, a nonprofit consortium of paper manufacturers, has developed a roadmap to decrease energy usage by 20 percent by the year 2020. The reduction could save the industry up to 80 trillion British Thermal Units (BTUs)—a traditional unit of heat—per year and as much as $250 million annually.

The Department of Energy's High-Performance Computing for Manufacturing (HPC4Mfg) program is a multilaboratory effort that seeks to use high-performance computing to address complex challenges in U.S. manufacturing. Through this program, Agenda 2020 partnered with Lawrence Livermore and Lawrence Berkeley national laboratories to optimize one of the most energy-intensive steps in the papermaking process—drying the wet paper pulp.

Efforts Focus on Wet-Pressing in Paper Manufacturing

The paper drying process involves a "wet-pressing" step, in which saturated, porous paper pulp is fed onto a moving belt of fine-mesh screening that holds a felt layer. The felt–pulp layers are squeezed through rollers and passed over steam-heated cylinders to remove the remaining water. However, as the layers leave the rollers and the pressure eases, the pulp sucks up some of the residual moisture from the felt, re-wetting the paper.



In paper processing, wet paper pulp and felt layers are pressed between rollers at high speed to remove water from the paper.

In collaboration with Agenda 2020, researchers at Lawrence Livermore and Lawrence Berkeley national laboratories are using the their supercomputering

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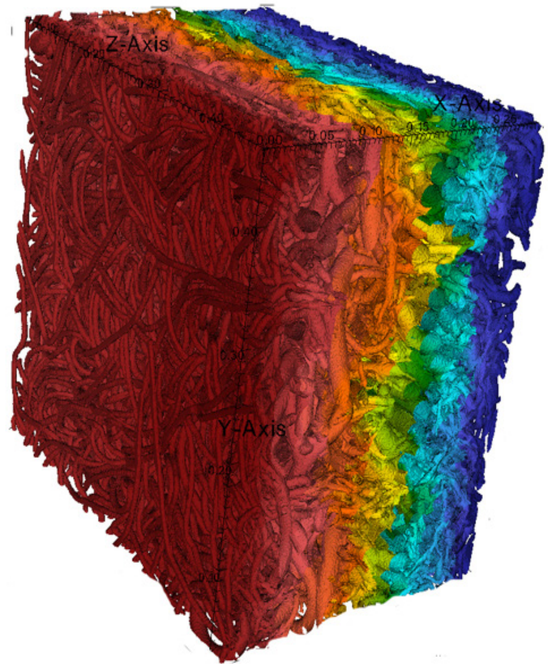
resources to study the re-wetting process. By leveraging the laboratories' advanced simulation capabilities, high-performance computing resources, and industry paper-machine press data, researchers are developing integrated numerical models to understand the physics of re-wetting and help the paper industry design more energy-efficient processes.

Collaboration Yields Fruitful Results

Using existing industry data, including felt measurements, computerized tomography (CT) images of the felt, and paper-machine press data, the laboratories developed a coupled-physics simulation framework to determine how water flows through porous paper pulp during and after the wet-pressing process. The model was designed to help researchers study how to increase paper dryness after pressing and before the final drying stage.

Lawrence Livermore developed the continuum simulation framework, integrating mechanical deformation and two-phase flow models, while Lawrence Berkeley developed a microscale flow model for the complex pore structures in the press felts, utilizing sophisticated modeling capabilities. Lawrence Berkeley used 50,000–60,000 cores at its computer facility to run these simulations, allowing the engineering-scale models to be more accurate by informing better parameterizations from microscale data.

The results from the initial continuum model clearly showed the deformation and dryness of the paper as it traverses rollers and provided a detailed numerical view of the process—an essential first step to optimizing paper drying. The model has been calibrated and validated by laboratory measurements and industry data, suggesting that the multiphysics modeling framework can adequately capture paper de-watering behaviors as observed at an operational scale. This information can be used to inform designs of more energy-efficient processes and equipment. The model results also indicate that mechanical properties of paper and felts play a key role in controlling paper de-watering processes, and thus require more rigorous evaluation through detailed laboratory measurements and high-fidelity pore-scale analysis.



This image depicts a simulation of pressure applied to felt used to absorb water in a paper drying process. (Photo courtesy of David Trebotich/Lawrence Berkeley National Laboratory).

Researchers are confident they can develop the computational models needed to invent optimized wet-pressing processes and achieve the goals set forth by the Agenda 2020 industry alliance. To create more accurate and reliable computational models, researchers will need to develop a fundamental understanding of the complex phenomenon associated with water flow and migration. Future work to address this problem will require a strong continued collaboration between computational scientists and experimental scientists from the paper-manufacturing industry, who can provide data on paper material properties, experimental data from controlled de-watering tests, and high-resolution micro-CT images.

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