Energy-Saving Paper Sensor Passes Major Milestone

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The paper industry is one step closer to saving millions of dollars each year. An innovative laser ultrasonic sensor designed and built by scientists from the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) was recently successfully tested at a paper mill in Jackson, Alabama.

The sensor measures a paper's bending stiffness and shear strength — two hallmarks of paper quality — as it speeds through a production web. By doing so, it can ensure that the optimum amount of raw material is used to make the paper, which could reduce the consumption of trees and chemicals and save the U.S. approximately $200 million in energy costs and $330 million in fiber costs each year.

"This is the first full-scale demonstration of the sensor on a commercial paper-making machine while it's in operation," says Paul Ridgway of Berkeley Lab's Environmental Energy Technologies Division (EETD), who developed the sensor with the project's principal investigator and fellow EETD scientist Rick Russo, in partnership with the Institute of Paper Science and Technology at Georgia Tech. The two-week test was conducted in February at a mill owned by Boise Cascade.

"Boise Cascade's engineers considered the trial to be quite successful, and are hopeful that a six-month trial will be conducted at the same mill," says Ridgway.

Eight years in the making, the sensor was funded by the Department of

Energy's Office of Industrial Technologies as part of a partnership to improve the energy efficiency of several industries. Under this program, the American Forest and Paper Association created Agenda 2020, which outlines ways in which the forest products industry will streamline its production processes.

Papermaking is an obvious candidate for improvement. To gauge paper quality today, a 15 to 30-ton paper roll is manufactured, and then a few samples are obtained from the end of the roll and analyzed for their mechanical properties by observing how they bend. If the samples don't meet certain specifications, the entire roll is recycled into pulp or sold as an inferior grade. To avoid this costly mistake, manufacturers often over engineer paper and use more pulp than necessary to ensure the final product isn't substandard.

This method consumes more raw material and energy than necessary, so the Berkeley Lab team developed a sensor that tracks papers’ flexibility on the fly, in real time. Specifically, the sensor measures the time it takes ultrasonic shock waves to propagate from a laser-induced excitation point on the moving paper to a detection point several millimeters away. The velocity at which the ultrasound waves travel from the excitation point through the paper to the detection point is related to two elastic properties, bending stiffness and out-of-plane shear rigidity.

The laser ultrasonic sensor conducts these measurements without touching the paper, an important advantage given that the paper moves at 20 meters per second (45 miles per hour) and the slightest contact can break the sheet and cause costly machine downtime, or mar lightweight grades such as copy paper and newsprint. The recent trial also boasted the highest sample speed ever reported for a commercial application of laser ultrasonics.

The next step in the project is to work with Boise Cascade to link the sensor with sophisticated feedback controls that maintain the paper's stiffness while it's being manufactured. ABB Corporation, which participated in the recent trial, is also likely to participate in this phase.

"Our technology will enable this real-time feedback control," says Ridgway. "And the successful mill trial shows we are one step closer to realizing it."

The mill trial is the latest in a string of successful real-world tests. In 2003, Ridgway, Russo and engineers from the Institute of Paper Science and Technology conducted a pilot-scale test of the laser ultrasonic sensor at Mead Paper Company's research center in Chillicothe, Ohio.

This test first demonstrated that the sensor's sophisticated hardware can successfully perform under the harsher conditions of an industrial environment, compared to a laboratory. In the sensor, a detection beam from a commercially available interferometer is directed toward a rotating mirror. The spinning mirror reflects the beam onto the paper as it courses along the production belt. Because both the beam and the paper are moving at the same speed, the detection beam remains fixed on the same point on the paper during their brief contact.

Next, an optical encoder determines when the detection beam is perpendicular to the paper, at which time a circuit fires a pulsed laser. This five-nanosecond pulse causes a microscopic thermal ablation of the paper, which is too small to visibly mar the paper but strong enough to send ultrasonic shock waves through the sheet. The waves propagate until they reach the detection beam. Because the laser is synchronized to only fire when the detection beam is perpendicular to the paper, the distance between the ablation point and detection point is known, and the waves' speed is calculated.

Source: Berkley Lab