Guided Acoustic Wave Monitoring of Corrosion in Recovery Boiler Tubing

By burning the black liquor produced during the kraft pulping process, the kraft recovery boiler allows the paper industry to produce over half of its own energy. In the recovery boiler, water-filled tubes absorb thermal energy. Exposed to combustion on the fireside and filled with pressurized flowing feedwater, recovery boiler wall tubes must withstand large and variable thermal and mechanical stresses. Furnace gas temperatures up to 2,500°F combined with the harsh molten salt environment can cause premature corrosion on the outer diameter of the recovery boiler wall tubes.

Extensive damage to recovery boiler tubes can result in a significant safety and environmental hazard. Considerable plant resources are expended to inspect recovery boiler tubing. Currently, visual and ultrasonic inspections are primarily used during the annual maintenance shutdown to monitor corrosion rates and cracking of tubing. If corrosion or cracking is detected, tubing must be repaired or replaced during the shutdown.

Guided acoustic waves have been developed as an inspection technique for tubular members for several years. The feature of this acoustic technique is its cost-effectiveness in inspecting long lengths of tubes from a single inspection point. Recent applications on nuclear steam generators have shown that guided acoustic waves can inspect entire cross-sections of tubes over 50 - 75 feet. This technique appears very promising for recovery boiler tube application by expediting annual inspection and possibly providing on-line periodic monitoring of tube integrity. A sensor for monitoring the integrity of recovery boiler tubes during the lifetime of the furnace allows timely replacement of cracked or corroded tubes.

Corrosion of tubing used in black-liquor recovery boilers is a major concern in all pulp and paper mills. Extensive corrosion in recovery boiler tubes can result in a significant safety and environmental hazard. Considerable plant resources are expended to inspect recovery boiler tubing. Currently, visual and ultrasonic inspections are primarily used during the annual maintenance shutdown to monitor corrosion rates and cracking of tubing.

Benefits for Our Industry and Our Nation

- Improved cost effectiveness of recovery boiler operation
- Reduced down time of powerhouse

Applications in Our Nation’s Industry

Recovery boilers burning spent black liquor provide half of the energy used by the paper industry. The new inspection technique can expedite annual inspection of tube integrity and improve the cost-effectiveness of recovery boiler operation.
**Project Description**

**Goal:** Development of a guided wave technique for boiler tubes to serve as a screening tool for two types of defects: circumferential cracks at restraints and wall thinning due to corrosion.

In the first year of this project, researchers studied issues related to implementation of guided wave inspection in the harsh furnace environment. Specific challenges included 1) generation of guided waves using sensors that operate at high temperatures, 2) determining the sensitivity of guided waves to the types of defects expected and 3) assessing thermal and mechanical effects of the furnace environment on guided wave propagation.

The first year assessment proved the feasibility of defect detection using long-distance guided acoustic waves. Theoretical modeling on guided wave mode propagation and power distribution around the tube was performed to analyze sensor design and determine optimal sensor characteristics, such as frequency, loading angle, and length. Results were used to design sensors and develop a complete system to inspect boiler tubing. Next, the sensors were tested on samples that had been pulled out of service to test the technique on real samples and damage. Determination of the sensitivity of guided waves in this application was performed using tube samples from collaborators and other industrial contributors.

Subsequently, sensitivity issues were addressed by narrowing the scope of the investigations to two specific types of defects, cracking at restraints and wall thinning. Piezoelectric and electromagnetic transducers were evaluated for their sensitivity to the two types of defects. Field tests were conducted at the Weyerhaeuser Prince Albert Plant to demonstrate the technology and determine issues for field use.

**Results**

- Detection of both real and simulated flaws was demonstrated on tubes in the laboratory. Water washing and wire brushing were sufficient preparation for the tube surface when using a piezoelectric transducer. The technique could detect defects with a minimum depth of 20% wall thickness.
- EMAT sensors show potential in minimizing surface preparation.

**Commercialization**

Lawrence Livermore National Laboratory has a patent for the application of this technology to boiler tubes. Alstom Power has written a letter expressing interest in commercialization.

**Project Partners**

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ABB Combustion
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