Using Multiphysics to Quantify Leakage Rates in New & Rehabilitated Sewer & Water Pipes

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Abstract

Traditionally, municipal sewer and water agencies have relied on acoustic data loggers and closed-circuit television cameras to inspect pipes for leaks. In addition, the same legacy techniques have been used to certify new and rehabilitated pipes as watertight.

Unfortunately, visually seeing and acoustically listening for defects has been problematic for an industry facing nearly a trillion dollars in capital costs to upgrade its fragmented network of sewer and water pipelines. Highly subjective results often relied on third-party data interpretation. Also, test data was neither easily repeated nor replicated when done by the same or different field inspectors. And, third-party contractors responsible for construction work, routinely were allowed to conduct their own field testing.

What the industry needed was an unbiased, machine-intelligent, technology capable of overcoming known weaknesses of legacy leak detection tools. Results needed to be automatically provided, allowing defects to be accurately and immediately identified so repairs or replacements could be done while crews were still in the field.

But, even if a solution currently existed, how could a game-changing innovation be scientifically accepted by an industry known for moving at a glacial speed, requiring a myriad of pipe materials, diameters, access, and traffic congestion, to be addressed?

The solution was combining desktop pipe simulations using the COMSOL Multiphysics® software with real-world field trials having challenging environmental conditions that could demonstrate independent, reliable and unambiguous results.

The science was fairly straightforward. Establish a low voltage electrical circuit, representing 6 AA batteries or 40 milliamps (mA), using water as a conductor to allow two ends of the circuit to connect and close the loop. Applied to an underground pipe, one side of the circuit would remain inside a non-conductive pipe (e.g. asbestos cement, brick, epoxy-coated ductile iron, high density polyethylene, plastic, resin-based liner, or vitrified clay pipe). The other side of the circuit would be located somewhere on the surface, connected to a grounding stake.

If the loop was never closed, i.e. an electrical connection was never made, the pipe would have no leaks. Conversely, if the loop was closed, i.e. an electrical connection made, then an opening or leak exists in the pipe allowing a pathway from inside the pipe to ground.

Since water flow and electric current are related, if the amount of current is measured, then the size of opening or leak size could be determined.

Utilizing the COMSOL Multiphysics® software, engineers were able to simulate a variety of sewer and water pipe configurations, including variations in pipe materials, diameter, ground cover, soil resistivity, and flow. Mechanical probes were then designed & developed to field test actual pipe conditions working with utilities with ongoing leak reduction programs and construction work requiring contractors to deliver watertight, leak-free pipes.

A major finding was that Cured-In-Place Pipe (CIPP) - a popular trenchless rehabilitation lining method for creating a pipe inside of an existing pipe - could have leaks in its liner not previously detected that could result in pinhole leaks, partial collapse, or failure of the pipe.

Figures used in the abstract

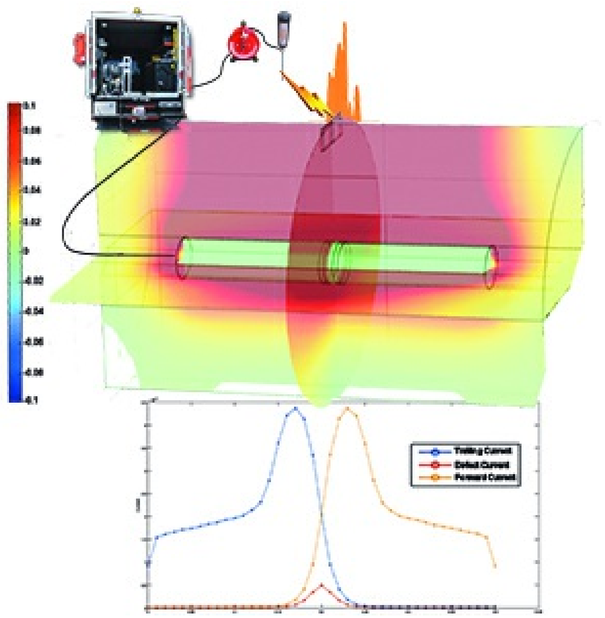

Figure 1: Electro Scan Focused Electrode Leak Location (FELL) precisely locates (within 0.4 inches or 1cm) & quantifies (in gallons per minute) each pipe leak.