Making the World A Safer Place to Live

Technologies that nondestructively examine materials and structures for flaws remain vital to assuring the reliability of America's industrial components and aging infrastructure

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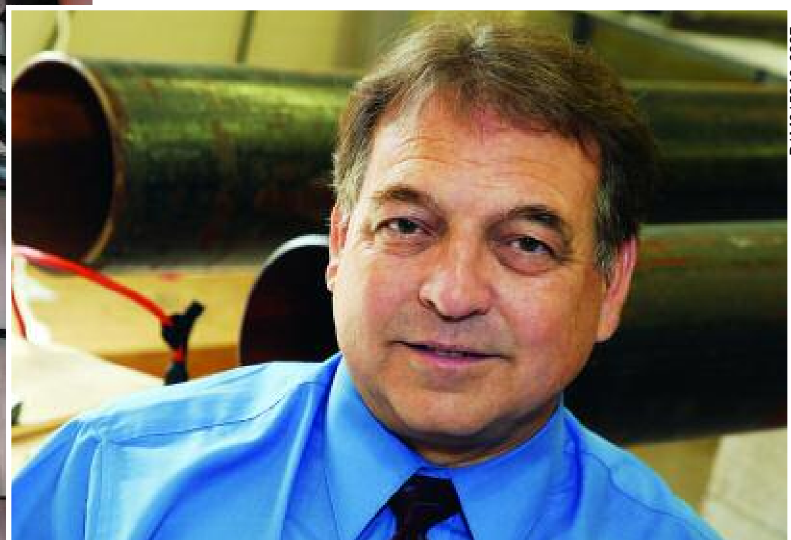
SwRI developed an ultrasonic inspection system (shown before delivery) that nondestructively evaluates nuclear plant reactor pressure vessels.



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Dr. Glenn M. Light is director of the Sensor Systems and Nondestructive Evaluation Technologies Department within the Applied Physics Division at SwRI. His expertise includes ultrasonic inspection technology and transducer design, eddy current probe design, digital radiography, computed tomography, infrared thermography and shearography. Light, a Fellow of the American Society for Nondestructive Testing, holds 14 patents and has written more than 100 papers on a variety of NDE topics.

Technology Today **talks to Dr. Glenn M. Light, who directs an internationally recognized team focused on the nondestructive evaluation of materials and structures used by the automotive, aerospace, construction, manufacturing, nuclear engineering, petrochemical and numerous other industries.**

What is NDE, and how does it help industry?

Nondestructive evaluation, or NDE, includes the scientific technologies used to determine the quality or operational state of a material or component without damaging the part. As an example, everyone is familiar with doctors taking an X-ray when they think you have a broken arm. The X-ray is an NDE technology that shows whether or not the bone is broken without requiring the arm be cut open to see the broken area.

X-rays and other NDE technologies are used in a wide range of industries to find defects in structures, piping and pressure vessels. In addition to X-ray, NDE technologies include ultrasonics (like sonograms), eddy current, electromagnetics, magnetic particle, penetrant and visual (including optical and electro-optical). Destructive testing can be an effective way to detect defects but, because it destroys the part, it is very expensive and can only be used on a sampling basis.

What are some of the methods for performing nondestructive evaluation?

There are various methods for performing nondestructive evaluations, such as acoustic emission, computed tomography, electromagnetic (eddy current), interferometry, radiographic, ultrasonic and visual. SwRI primarily uses ultrasonics, eddy current, magnetostriction, magnetic particle, liquid penetrant, visual, infrared thermography, X-ray radiography and computed tomography.

Ultrasonics, infrared thermography, radiography and computed tomography are useful for volumetric defects. Eddy current, magnetic particle, liquid penetrant and visual are primarily for surface defects. Ultrasonics usually require a liquid to be used between the sensor and the part so if the part can't tolerate liquid ultrasonics can't be used. Radiography and computed tomography use X-ray sources and can pose the obvious health risks. Magnetic particle and magnetostrictive sensors require the use of magnets. The appropriate NDE method is determined by the physical properties of the item being inspected and the type of defect that must be found.

How are SwRI NDE capabilities different from those of its competitors?

SwRI focuses on using the physics and science of sensors and sensor technologies to *develop* solutions to NDE problems, including new sensor technologies or sensor formats. Often our competitors use *available* NDE sensor technologies.

In addition, SwRI's technical breadth offers our clients a complete solution — from sensor design and fabrication, to system development and integration, and even to field use. We also have patent protection on magnetostrictive sensor technology as an NDE tool.

Nuclear power plant inspection is how SwRI moved into the NDE area. Tell us about that.

SwRI got started in the NDE business because of the need to inspect nuclear power plants that were opening in the United States in the early 1970s. We were very much involved in developing the engineering codes for nuclear power plant components at that time and realized there would be a need to inspect the plants. We were in the unique position of developing requirements for inspection and having scientists and engineers that could develop technologies needed to meet new inspection requirements.

This eventually led to the creation of a division with strong technology research capabilities, field service inspection capabilities, and development capabilities for mechanical systems, data acquisition and analysis systems, and inspection procedures. We initially had few competitors in the market. However, the competition grew over the years and by the late 1990s it became apparent that the inspection service capability would not continue to be a good market for SwRI, which is more research-oriented. Over the years, the research and development part of our business has grown into other areas and remains a viable business.

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SwRI engineers built a magnetostrictive sensor system to inspect the three-inch-diameter suspenders of bridges. From one probe location, the low-cost technique detects geometric features and defects in the suspender ropes without the need for paint removal.

SwRI is a pioneer in magnetostrictive sensor technology for nondestructive evaluations. Give us a bit of history on MsS and its uses.

Dr. Hegeon Kwun, a staff scientist at SwRI, began investigating the magnetostrictive property in the late 1980s to generate ultrasonic guided waves in bridge wires and cables so they could be inspected for defects. This research led us to understand that magnetostrictive technology could be used to inspect ferromagnetic piping.

In 1988, the magnetostrictive sensor pipe and tube inspection and evaluation system won an R&D 100 award. In early 2000, our team developed a method to generate guided waves in nonferromagnetic materials by first generating the waves in a thin strip of ferromagnetic material bonded to the nonferromagnetic material to be inspected. Since then, MsS technology has been used to inspect cables, anchor rods, piping and long plates, and has even been used for sensing sudden impacts. SwRI has

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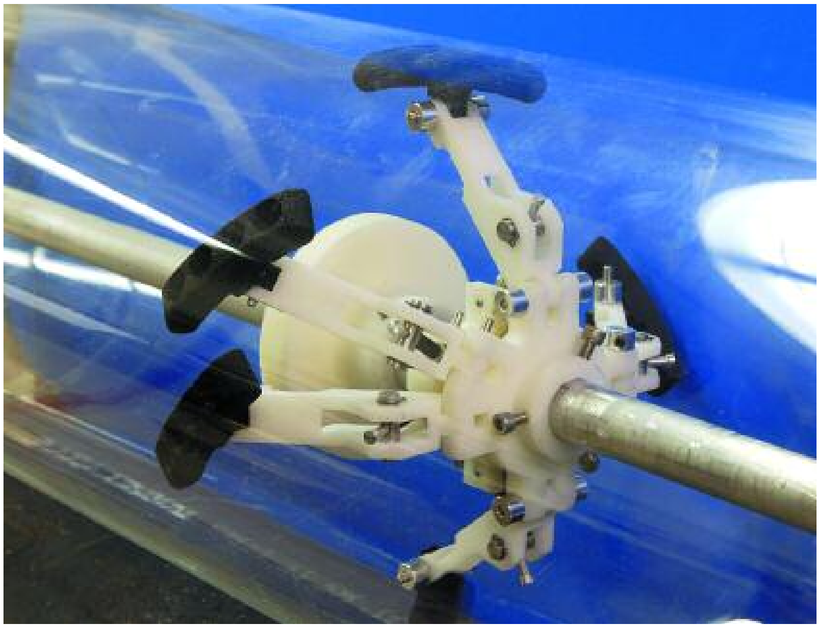

Internal restrictions in pipelines prevent conventional inspection pigs from traveling through unimpeded. For the Department of Transportation, SwRI is developing a remote-field eddy current system that collapses to move past pipeline obstructions, then expands to complete the inspection.

received approximately 25 patents related to MsS since this research began.

In 2006, *R&D Magazine* selected our MsS heat exchanger probe as one of the 100 most significant developments of the year (see article, page 11).

How do industries typically fit nondestructive evaluations into their inspection cycles? What is the ideal application of NDE in your view?

Industries often design components and develop materials to satisfy a need thinking that the component or material can be fabricated with no defects. Then the first item comes off the line and someone notices a defect. At that point, everyone becomes interested in how to inspect the part to ensure the defect is no longer present. We spend a lot of time trying to develop inspection processes for components and materials already fabricated.

The ideal approach is to apply "access engineering" where SwRI NDE experts interact with the manufacturers of the components or materials at the development stage. This provides an opportunity for everyone to understand the defects that need to be found, determine the best inspection method and possibly even gain some knowledge that will lead to design modifications to ensure certain inspections can be accomplished. The nuclear power plant industry adopted this approach after a number of power plants were built and found to be almost impossible to inspect.

What about the application of NDE to aging infrastructures?

The design lifetimes for many aerospace, power generation, petrochemical and other vital systems are fast approaching or have already been exceeded, and NDE certainly plays a role in assuring continued reliability. Our staff is known for developing reliable, cost-effective techniques for inspecting the infrastructure.

We are using magnetostrictive sensors as a health monitoring technology for piping. We also just finished a multidivisional project for the Defense Advanced Research Projects Agency aimed at developing a magnetostrictive multi-layer thin-film sensor that could be deposited onto a part and used at high temperatures with wireless communication. The technology was tested to 500 degrees Fahrenheit, but we're looking to extend this capability to 1,000 to 1,200 degrees F.

We've adapted this thin-film sensor to help monitor the health of aircraft components (see sidebar, opposite page).This relatively new field, called structural health monitoring, is receiving a great deal of attention because of its potential to eliminate scheduled manual inspections in favor of real-time monitoring. Here, NDE sensors are built into a structure to help detect cracks, corrosion, pits and inclusions as they occur, before they can compromise structural integrity. This predictive maintenance approach ultimately helps to assure the integrity of vital systems as they approach their design lifetimes.

NDE is occasionally criticized for being unreliable. How does SwRI verify the accuracy of its NDE methods?

The human factor involved with inspections is what tends to draw the criticism. Most nondestructive evaluations require an

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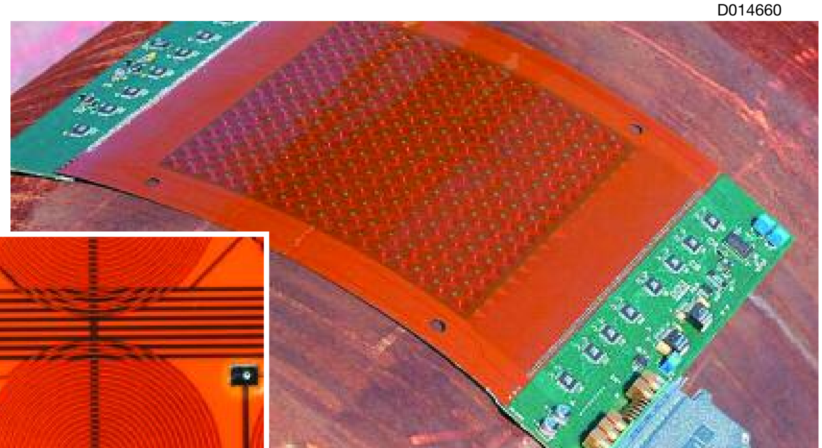

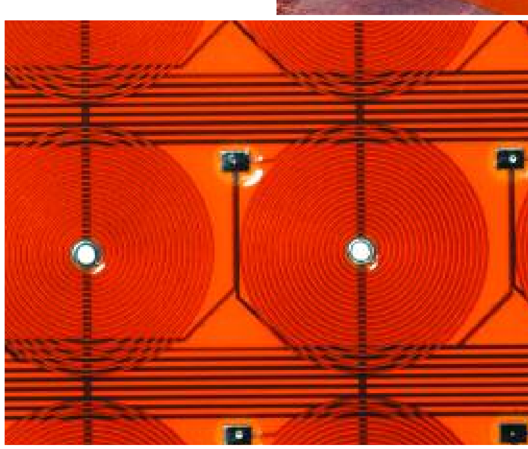

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The eddy current conformable array developed at SwRI assesses external corrosion of pipelines in the field. The flexible printed circuit array (shown in exploded view) is placed over a corroded pipeline to produce a color map of corrosion depth, as well as to calculate the safe operating pressure of the pipeline.

inspector. Mental or physical fatigue, emotional issues or a myriad of other problems can affect the reliability of the inspection.

SwRI has long promoted the use of mechanical scanners and digital data acquisition and analysis systems that minimize the need for human intervention as much as possible. This automatically improves reliability. SwRI has also engineered techniques to obtain more consistent sensors. In addition, when these types of solutions are not possible and a manned inspection approach is necessary, SwRI emphasizes the use of a logical and scientifically sound calibration process and inspection procedure.

SwRI most often applies NDE methods for the prevention of structural failure and has only recently applied them to forensic investigations, such as followed the *Columbia* accident. Tell us about your move into that area.

The forensic side of our NDE work is very small. We did get heavily involved with the investigation of the *Columbia* accident, and we've been involved in other failure investigations, primarily in support of SwRI failure analysis projects in the Mechanical and Materials Engineering Division. This involved inspection of turbine blades and some structural aircraft parts. The downside to this work, and the primary reason we are careful about taking it on, is the propensity toward litigation in forensic-type investigations. As an independent R&D organization, we avoid these situations as much as possible.

What do you see for the future of NDE?

There's no doubt that advanced materials, such as composites, will continue to bring new opportunities. At the same time, our aging infrastructure will remain a high priority. However, we expect our clients to increasingly build NDE sensors into their systems, either by inserting them during the manufacturing process or by building them into the structure itself. In either case, rapid advances in computing and the development of new NDE technologies will enable sensors to inspect structures to assure integrity — and therefore safety — more quickly and more accurately than ever before. ❖

*Comments about this article? Contact Light at (210) 522-2218 or glenn.light@swri.org. To discuss this article see **www.swri.org/forums.***

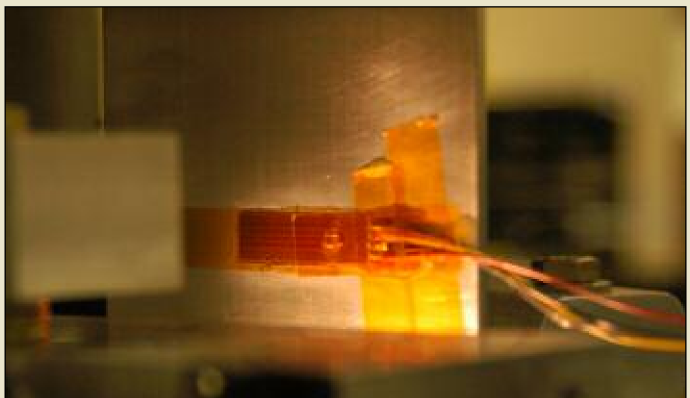
New multilayer thin-film sensors enable fast, efficient monitoring of aircraft defects

As aircraft reach or exceed their design lifetimes, the U.S. Air Force is turning to advanced nondestructive evaluation methods to determine their fitness for continued duty. SwRI developed a flexible thin-film deposition process (as a follow-on effort to a recent project funded by the Defense Advanced Research Projects Agency) that will enable the fabrication of thin magnetostrictive sensors that can efficiently detect and monitor defects in aircraft without the need for costly teardowns or unnecessary inspections.

SwRI pioneered the use of MsS technology as a nondestructive evaluation tool for the pipeline industry. The method uses guided waves to rapidly detect corrosion and defects for assessing overall pipeline integrity. A magnetic field around the pipe generates the guided waves with a ferromagnetic strip and coil; however, this external magnet is impractical for the small components and confined spaces aboard aircraft.

"What we needed was an improved, lightweight, low-profile evaluation sensor that could maintain a residual magnetic field without the need for an external magnet," said Senior Research Engineer Clint J. Thwing of SwRI's Sensor Systems and Nondestructive Evaluation Technology Department.

Using internal research funds, the SwRI team developed a process for manufacturing thin films that, when combined with magnetostrictive sensor technology, effectively detect flaws without the need for an external magnet. Deposited in an ultra-high vacuum environment, the thin films are layered with iron cobalt and iron terbium, then heat-treated. SwRI applied the multilayer deposition process to low-oxidation aluminum foil so that the thin film would be pliable and easy to apply. The technique for manufacturing multilayer thin-film magnetostrictive sensors is reproducible, and the resulting sensors have been shown to effectively monitor crack growth and determine the approximate size (cross section) of defects on a simulated A-10 aircraft structure.



SwRI engineers developed a thin-film magnetostrictive sensor to detect and monitor cracks growing in aircraft components. As SwRI engineers applied loads, the sensor successfully tracked the growth of a crack.

Magnetostrictive sensors used by the pipeline industry also are limited by a "dead zone" — the distance associated with the time required for the excitation pulses to saturate the receiver. At 32 kHz, the dead zone extends 2 to 3 feet. This distance is inconsequential when testing a miles-long pipeline, but in aircraft bulkheads and fuselage components, the region to be inspected is usually only a few inches from the site of the monitoring probe. The new method minimizes the dead zone by using a much shorter wavelength or higher frequency signal.

"This new MsS technology is also ideal as a health and usage monitoring system, or HUMS sensor," said Thwing. "Installed as onboard sensors and data acquisition systems, HUMS can help reduce costs, improve readiness and increase safety by identifying mechanical problems or maintenance issues while the aircraft remains in service."

With additional development, the new MsS technology will address the need for monitoring the structural components of today's high-cycle aircraft, such as T-37 and T-38 trainers, as well as A-10, F-16, F-15 and other military combat aircraft. It also has potential for commercial fleets.