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Safe and Sound

Researchers develop a new approach to continuously monitor the health of the next generation of nuclear power plants

Nuclear power plants are producing electricity at record rates, providing about one-fifth of our nation's electricity. Helping to keep them running — and more importantly, running safely — are nondestructive evaluation technologies. By providing the ability to peer inside critical pipes and structures without having to destroy them, NDE has become essential to the nuclear power industry.

Now, Norio Nakagawa, a physicist at the Ames Laboratory, and his collaborators are applying decades of NDE experience to future nuclear reactor designs. "We are giving NDE consideration while the system design is being developed. That's rather new in the nuclear business," Nakagawa says.

The researchers are about two years into the three-year project, part of the U.S. Department of Energy's Nuclear Energy Research Initiative.

NERI's purpose is to address the long-term barriers to expanding the use of nuclear power to ensure that the U.S. can meet its future energy and environmental needs. The Ames Lab portion aims to develop concepts for on-line health monitoring of nuclear reactors to enhance the safety and economy of advanced nuclear power plants. In addition to Nakagawa, the research team includes R. Bruce Thompson and Feyzi Inanc of the Ames Lab as well as nuclear power industry representatives.

The on-line system will provide continuous monitoring so that deviations from normal operation can be detected immediately and problems addressed before they become serious. Moreover, on-line monitoring can be done remotely, greatly reducing exposure levels of maintenance workers.

Economics are also important, of course. "For

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Ames Lab scientist Norio Nakagawa is studying the use of eddy current inspection and other nondestructive evaluation technologies to continuously monitor the next generation of nuclear reactors.

nuclear power to be able to compete with other methods, it has to improve its operational costs," Nakagawa says. One way new reactor designs achieve this goal is by extending the refueling cycle to four years or more. This, however, makes today's "outage-based maintenance" approach problematic, where critical inspections are done when the plant is shut down for refueling, typically every 18 months. With the help of on-line health monitoring, designers of the next generation of nuclear reactors can reach the four-year goal to create plants that are safe and economically competitive.

On-line Sensors

The Ames Lab team is developing concepts that can be engineered into advanced nuclear reactor systems. "Our integrated inspection approach will help these systems achieve the goal of greatly enhanced safety and reliability," Nakagawa says. He adds that the team's concepts are generic enough to be used by designers of many types of nuclear power systems.

"The key is the on-line, integrated monitoring approach," Nakagawa says. The first step of the project has been to develop the overall concept. "Of course, there have been on-line sensors — temperature gauges, and so on — but we are expanding the scope of the on-line sensor concept to the next level," Nakagawa says.

The second step of the project is to identify the most critical areas in need of on-line monitoring and then develop NDE concepts to address them. The Ames Lab researchers are also developing sensitivity estimates for each technology. "That will tell us how much sensor output to expect," Nakagawa says.

The first area is steam generator tubing. As the name indicates, a steam generator boils the secondary water into steam that goes to the turbine. Steam generators require a fair amount of tubing to maximize heat transfer efficiency from the core to the steam. "The tubing is very important in terms of safety inspection," Nakagawa says. One potential problem is magnetite deposits, iron oxide that builds up where the coolant in a steam tube evaporates. The magnetite buildup reduces heat transfer and creates a corrosive environment.

To continuously monitor magnetite buildup, the Ames Lab team is proposing a built-in eddy current sensor. Essentially, EC sensors work by using a probe made of a wire coil. An alternating current passing through the probe generates a magnetic field around it. The probe's changing magnetic field generates current flow, or eddy currents, in the material. In turn, the eddy currents produce their own magnetic fields that generate reaction voltages in the coil. The resulting changes in coil impedance can be measured to gather information about the test material.

EC sensors can be made tough enough to survive the elevated temperatures and radiation found inside a nuclear reactor. For steam generator inspections, Ames Laboratory researchers are proposing a system in which an EC coil encircles tubes to provide a way to detect potential magnetite deposits inside the tube. One coil might even be able to monitor several tubes inside of it.

Use the Force

Another critical inspection job is determining the structural integrity of steam generator tubes, especially where the tubes are attached to key support points, often by welding. For these areas, the researchers are studying ultra-sonic testing using an electromagnetic acoustic transducer. Basically, an EMAT generates a static magnetic field and alternating electric field inside the test piece placed nearby. The resulting Lorentz force acting on the test material generates sound waves that travel some distance. At the receiving end, these sound waves, in combination with the magnetic field, produce an electrical voltage that can be measured to provide information about the test material condition.

Unlike the more familiar type of ultrasonic testing used in medical applications — in which the sensor is coupled with the body via a thin layer of fluid or jelly — EMAT ultrasonic testing does not require that the sensor and sample be in contact. That, and the ability for EMATs to withstand high temperatures and radiation, makes EMAT UT an ideal NDE technology for nuclear power plants.

Moreover, EMAT UT can be used to send an acoustic wave, called a guided wave, down a tube to inspect its entire length. "Hopefully, our studies will tell us whether or not we can actually make a wave travel as far as needed, about 10 meters," says Nakagawa. The researchers are also exploring the use of EMAT UT for monitoring the reactor pressure vessel for cracking.

On-chip Detectors

Another area under study is how to better monitor radiation levels in the reactor core by using radiation detectors, one more proven NDE technology. The technology may be used to monitor reactor fuel activities and perhaps other critical events.

The concept relies on new semiconductor-based radiation sensors. These on-chip detectors, about one-fourth the size of a dime, can withstand the high temperatures and radiation found in a nuclear reactor. The researchers are creating models to estimate gamma ray radiation intensities as functions of locations over the reactor life to determine how to best use these detectors. ■

~ Robert Mills

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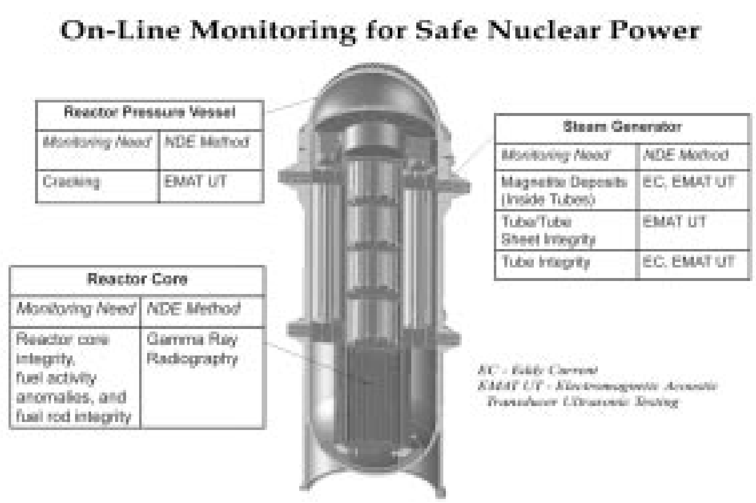

Ames Lab researchers have introduced the concept of on-line sensors to monitor the integrity of the next generation of nuclear power systems. These concepts, which use nondestructive evaluation methods, are being made available to designers of the advanced reactors such as the one shown here.