Research on Advanced ISI Technologies

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Development of advanced nondestructive evaluation (NDE) technologies will play a crucial role toward long term maintenance and safe operation of the current fleet of nuclear power plants (NPPs) in the United States. Although significant progress has been made in this area in the past three decades, extending the life of existing plants will undoubtedly require deployment of improved sensor technologies with higher spatial resolution and sensitivity for in-service inspection (ISI) of components and structures. Employment of portable or easily transportable inspection systems in conjunction with on-line monitoring sensors that can operate under harsh environmental conditions (i.e., continuous operation at elevated temperature, pressure, radiation) could significantly improve the reliability of diagnostic and prognostic methods. To address emerging industry and regulatory concerns, specialized sensors may have to be developed to help resolve potentially challenging inspection issues. Successful implementation of on-line imaging and continuous monitoring technologies, which inherently generate large amounts of data, will only be feasible through employment of efficient data screening and analysis algorithms. Thus, parallel efforts will be needed on development of advanced data processing and management tools. Computer aided data analysis software could further improve NDE reliability by reducing or eliminating operator related errors. Finally, the use of elaborate numerical models could provide a reliable and cost-effective alternative to time-consuming experimental efforts for assessing the reliability of NDE techniques and also as an efficient means for optimizing new probe designs for complex test conditions.

Extensive research activities associated with life-extension and management of existing light water reactors have been sponsored over the years by the U.S. NRC and the DOE. The reliability of a wide range of NDE technologies including electromagnetic and acoustic methods have been evaluated in application to ISI of NPP components (e.g., tubing, piping, pressure vessel, etc.). As plants age and as new defect specific management schemes are implemented, new experimental data and the predictive correlations and models need to be developed in order to permit the NRC to independently evaluate the integrity of NPP components. The ability to reliably inspect a test piece is a critical factor in successful application of any NDE method. Thus, the design of replacement parts employing improved materials and manufacturing processes must be done in consideration of inservice inspectability of components. Effectiveness of improved diagnostic methods will depend heavily on the reliability and effectiveness of the sensor output. Emerging and new NDE techniques therefore must be evaluated with respect to their range of applicability. High-resolution eddy current (EC) array probes are a promising method for more extensive ISI applications to help improve detection and characterization of incipient degradations. Specially designed multi-coil transducer configurations could significantly increase the EC depth of penetration and improve signal-to-noise ratio that is necessary for the inspection of relatively thick clad piping. The potential for on-line measurement of residual stress using EC technology should also be explored. Emerging NDE techniques such as phased-array UT and synthetic aperture focusing should be further evaluated by using a performance-based approach. Validation of new and emerging NDE techniques is expected to be done in part by using destructive examinations. These studies can take advantage of more precise laboratory based NDE techniques such as X-ray computed tomography, thermal wave imaging, and neutron diffraction. Other examples for potential areas of research include evaluation of portable or embedded RF sensors for rapid inspection of containment and other concrete structures and more extensive assessment of new acoustic and ultrasonic leak detection and monitoring technologies for the reactor coolant system.

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