Recent Accomplishment in Ultrasonic Health Monitoring for Nuclear Power Plants

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Today's NPPs follow prescriptive requirements for maintenance and inspection of components, structures, and systems. While many of these requirements are derived from several decades of operational experience, they nonetheless do not take into consideration the actual equipment conditions in determining the need for maintenance and operational adjustments. Continuous condition monitoring in current nuclear power plants is limited to sensor technologies that must be applied externally to already existing components and systems. On-line continuous condition monitoring using non-destructive or non-intrusive testing, such as ultrasonic testing, radiography, infrared thermograph, and motor current signature analysis, have been popular in NPPs for over a decade. But advanced monitoring technologies, including the use of fusion sensors, laser and laser-ultrasonic sensors, and fiber optic sensors, that have been used in chemical and coal plants, have had no or limited application in the NPP industry.

Keywords: PSI/ISI, Risk informed inspection, Advanced condition monitoring

1. Introduction

This review of nondestructive evaluation (NDE) techniques that have been used to health monitoring nuclear power plants components. Especially, methods based on acoustic phenomena, such as ultrasonic techniques have been reviewed.

The reliability for safety and cost effective operation of nuclear power plants are based on the effectiveness of nondestructive evaluation(NDE). It is well known that in-service inspection(ISI) plays an important role in assuring the integrity of the structure or component of nuclear power plants. Pre-service inspection(PSI) and ISI in Korean nuclear power plants are performed according to ASME code Section XI every 10-year period, because ASME code mandates that PSI/ISI are performed by NDE.

These activities include ASME code section XI requirement, Nuclear Regulatory Commission, legislative requirement, and other specific initiatives.

In recent, Performance Demonstration(PD) program of NDT for nuclear power plants has been launched out in Korea to improve reliability of testing skill. In this program, there are two different methods including both ultrasonic test for piping, bolt, reactor vessel, dissimilar piping weld and eddy current test for qualified data analyst and site specific PD.

2. Issue of Health Monitoring in NPPs

Today's NPPs follow prescriptive requirements for maintenance and inspection of components, structures, and systems. While many of these requirements are derived from several decades of operational experience, they nonetheless do not take into consideration the actual equipment conditions in determining the need for maintenance and operational adjustments. Continuous condition monitoring in current nuclear power plants is limited to sensor technologies that must be applied externally to already existing components and systems.

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A variety of advanced sensors and sensor systems, including acoustic, magnetic, optical fiber and electrical excitation, are available for a range of applications. Generation IV NPPs consider a variety of design concepts, including water-cooled, gas-cooled, metal-cooled, and others. There are issues specific to new reactors that must be addressed to ensure they are managed and operated in the safest way possible. It is important to apply a sensor technology that is effective for obtaining the types of signals that will provide an accurate and reliable indication of the performance and condition of a specific type of NPP component or structure. Robust data acquisition and processing systems are required to record and transmit large influxes of sensor signal data.

Additionally, advanced computational software must support the recording, analysis and interpretation of sensor signal data to provide effective output to a user from the condition monitoring system.

The software includes algorithms for pattern recognition and data reduction that relates signal patterns to multi-parameters that in turn provide direct information about the performance of components, structures, and systems in terms of degradation and failure conditions.

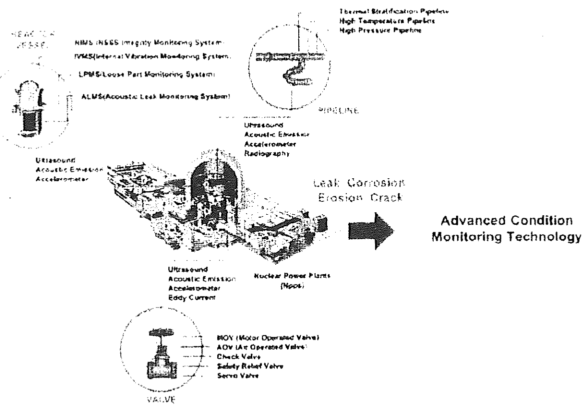

Fig.1 Typical condition monitoring technique of NPPs.

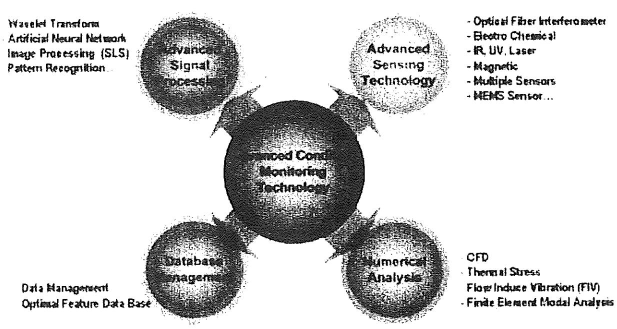

Fig.2 Key factors for condition Monitoring technique of NPPs.

3. Application of Ultrasonic Health Monitoring for Secondary Piping using Guided Wave.

Elastic guided wave technique has been known as a promising tool for a long-range inspection of pipes. Ultrasonic guided wave technique provides us with decent initial screening tool in much more faster and efficient manner. However, such advantage can be obtained only through a proper mode selection and tuning scheme. For the more, the mode conversion analysis becomes inevitably necessary for a quantitative interpretation of scattering data [1-2]. Guided waves are associated with various possible wave modes propagating in wave guides such as pipes. Tubing and piping structures are excellent waveguides. The benefits of using ultrasonic guided waves in large scale inspections are cost effectiveness, time efficiency, and improved sensitivity using multiple guided wave modes.

Figure 4 shows a schematic diagram of guided wave inspection. A high power pulser / receiver (Ritec RAM 10000) is used to generate guided wave mode in pipe and the time domain signals are displayed on a digital oscilloscope.

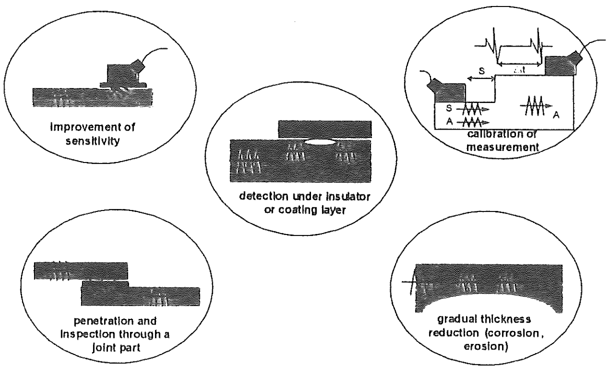

Fig. 3. Various Applications of Guided Waves.

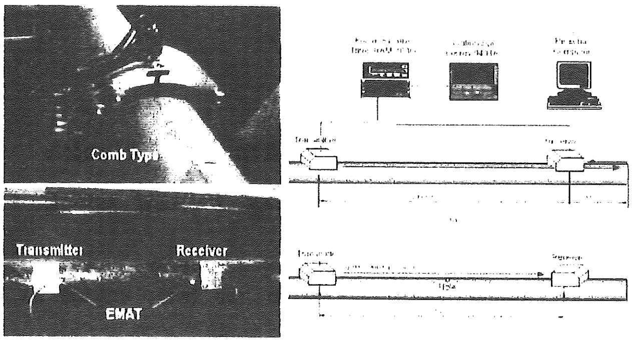

Fig. 4. Configuration of the guided wave inspection.

Figs. 5 and 6 represent the experimental setup for angle beam test and its sample result for long-range defect location.

As illustrated in Fig. 7, the modified immersion type angle beam probe provides us with a promising feature of guided wave probe enhancement with a good signal to noise ratio. The present angle beam technique can be also applied with multi probes circumferentially arranged with uniform span from each other for inspecting a pipe of larger diameter. Fig. 7 presents that the two drilled holes of 50 and 100 % depths respectively can be clearly located based on this technique. Three angle beam probes of 1.0 Mhz center frequency were employed and excited in phase. This result shows a good example of the variety of guided wave probe design based on the combination of angle and array beam techniques.

Fig. 5 Experimental setup with the modified immersion type angle beam probe

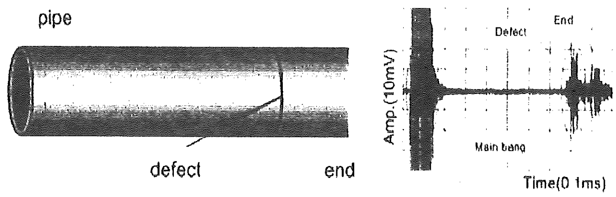

Fig. 6 Long-range defect locations by the angle beam technique.

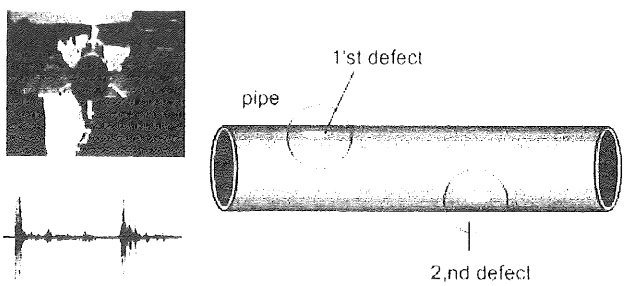

Fig. 7 Multiple defects location in a pipe with 254 mm O.D. and 5mm thickness based on the combined technique of angle and array beam incidence

Figure 8 shows a typical application of PHWR feeder pipe inspection using guided wave. This technique is relative simple and easy to implement at the field inspection, and it be useful for accurate location and size of the flaws.

But it is expected heavy radiation exposure for examiners and only possible to the accessible bent pipe [3].

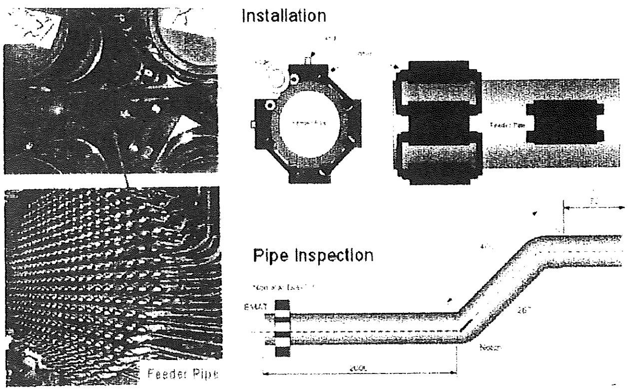

Fig. 8. Configuration of guided wave inspection of cracks in PHWR feeder pipe.

4. Conclusions

Continuous health monitoring in current nuclear power plants is limited to sensor technologies that must be applied externally to already existing components and systems.

The number of available NDE techniques and their phistication has increased in recent years. This trend is expected to continue with the advances in data processing and sensor technology. The primary issues is therefore the culmination of the research into better design and maintenance of components of NPPs and in better structural and material inspection tools and standards.

Acknowledgement

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