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Acoustic Leak Detection Testing Using KAERI Sodium-Water Reaction Signals for a SFR Steam Generator

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1. Introduction

The results of an experimental study of water in a sodium leak noise spectrum formation at 0.004~0.54 g/sec, various rates of water into a sodium leak, smaller than 1.0 g/sec, are presented. We focused on studying a micro leak detection with an increasing rate of water into sodium. On the basis of the experimental leak noise data manufactured in KAERI the simple dependency of an acoustic signal level from the rate of a micro and small leak at different frequency bands is presented to understand the principal analysis for the development of an acoustic leak detection methodology used in a K-600 steam generator.

2. Background

The outflow with a flame generates a crack growth in a tube wall, by which a material defect causes a complicated configuration which is distinct from a cylindrical, rectangular or slot-hole channel.

Applied assumptions to simplify the calculation with the Reynolds number and Mach number were permissible in terms of their insignificant impact on the acoustic characteristics of a leak noise. For the determination of the range of a bubble mode of a leak [1], a quasi-static equilibrium of a hydrogen bubble in liquid sodium at the time of its separation from the output section of a channel was assumed as shown in Fig. 1.

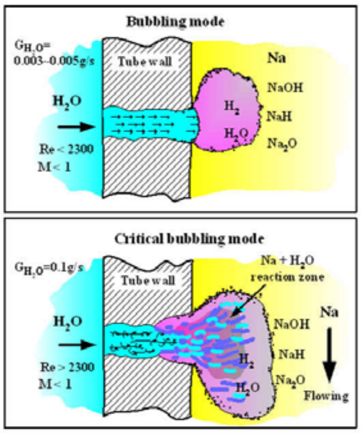

Fig. 1. Flame in an outflow of the sodium-water reaction.

3. Experimental Works

The sodium-water reaction experimental works of the steam injection at a sodium temperature of 300~350°C were in a sodium test facility of the KAERI. The container was constructed with stainless steel 304, and its sizes are height 2000mm, diameter 300mm and thickness of the wall 5mm. The test materials used for injection were 2.25Cr-1Mo steel and 9Cr-1Mo steel.

The injection in the KAERI experimental works was the steam at a range of 0.8~12 kg/cm^2, 300 °C and 0.004~0.54g/sec. The acoustic emission sensor was DECI-1000H, and the wave-guide was a diameter of 5mm and a length of 500mm.

Fig. 2. Sodium-water reaction test facility at KAERI.

This acoustic leak detection system as shown in Fig. 3, constructed with LabVIEW consists of the unit for preprocessing the signals and the neural network having the input of its feature vector by a pre-processing, after learning with the sodium-water reaction noises and the mixed noises of a sodium-water reaction signal and a background noise of the PFR S/H(super-heater).

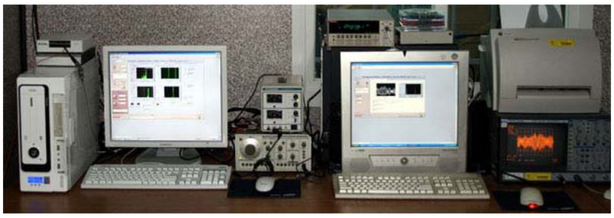

Fig. 3. The On-line acoustic leak detection system developed in KAERI.

4. Results and Discussion

4.1 Acoustic noise measurements and FFT analysis

Acoustic noise measurements were conducted using the sodium-water reaction test facility at KAERI. By using a water-steam into liquid sodium injection with flow rates at 0.004 ~0.54g/sec. Fig. 4 presents the raw signals for different rates of the water/steam-into-sodium leaks. At a leak, a flow rate increase with the acoustic signal power was observed, plus oscillations of the separated bubbles were also clearly seen. The analysis of the Fast Fourier Transform (FFT) spectra in each frequency band selected by us allows for a judgment to be made on the distribution of the hydrogen bubble radii, their magnitude relation, and the dynamics of a bubble cluster.

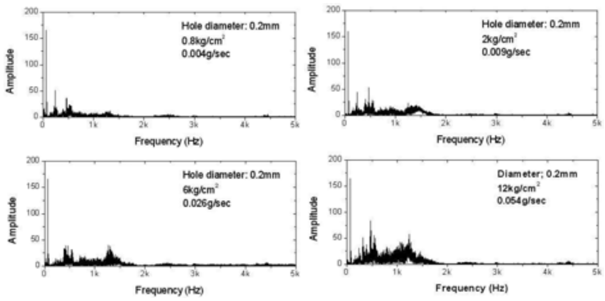

Fig. 4. Relative averaged FFT spectra for different water-in-sodium injection rates.

4.2 Performance of the acoustic leak detection system using test signals

The PFR S/H background noises are for developing the sodium-water reaction detection methodology, like as the signals generated as the background noises which the signals are generated suddenly.

As for the previous acoustic leak detection methodologies [2], the preprocessing unit is used for the frequency band for the FFT power spectrum analysis and the 1/3 Octave band analysis function, and in some cases its processing unit is used for the 1/6 Octave band analysis and 1/12 Octave band analysis. If the frequency band of the background noises is closed and very similar to the frequency band of the SWR signals, the detection methodology is used with the Octave band of a higher order as 1/12 Octave band compared with a lower order in the Octave band analysis.

After its preprocessing, it is again calculated for the input data of the feature vector for learning about and testing the neural network, and then after an optimizing by a learning of the weight values of the neural network.

4.3 Results of performance test

A detection tool performance of the developed acoustic leak detection methodologies [2] by using the sodium-water reaction noises controlled with the attenuation of the leak signal against the background noise of the PFR super-heater was shown to detect a leak according to the learning conditions of the neural network in Fig. 5. With the performance results by the developed acoustic leak detection methodology it was possible to detect a leak up to S/N: -20dB, in the case of a leak rate of 0.1 g/sec to detect a leak up to S/N: -27dB in the case of leak rate of 0.27 to 0.54 g/sec.

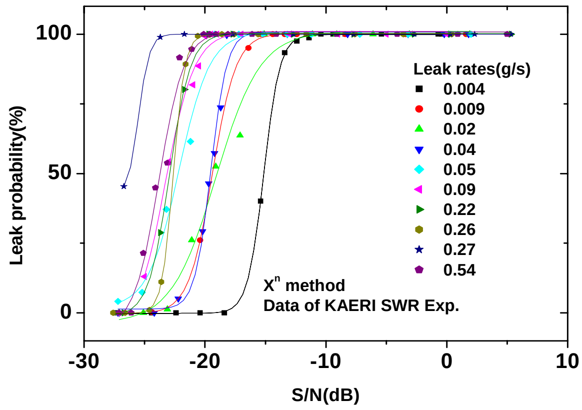

Fig. 5. Performance test results using developed acoustic leak detection methodology.

5. Conclusion

The results established in our study are favorable for an early detection of small and micro leaks. In the case of a micro-leak in the range of a rate from 0.004 ~0.54 g/sec and when the S/N ratio is expected to be 1/100 ~1/500.

To protect a SG from damage from a tube bundle owing to the origin of secondary leaks it is necessary to detect a leak during its self-wastage, up to the moment of an outflow diameter. With the performance results by the developed acoustic leak detection methodology it was possible to detect a leak up to S/N: -20dB ~ -27dB. At present, the developed system has no errors for detecting a leak, but in the future it must be absolutely assured that it has no error for detecting a leak.

ACNOWLEDGEMENT

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[2] Tae-Joon Kim, Ji-Young Jeong, and Seop Hur, Performance Test for developing the Acoustic Leak Detection System of the LMR Steam Generator, Transactions of the Korean Nuclear Society Autumn Meeting, Transactions of the Korean Society Autumn Meeting, Busan, Korea, October 27-28, 2005.