Transactions of the Korean Nuclear Society Spring Meeting
Gyeongju, Korea, May 29-30, 2008

Piezoelectric and Sensitivity Evaluation of Acoustic Emission Sensors for Nuclear Power Plant Valve

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1. Introduction

A lot of valves are used in the power plant. The operation safety test and the valve inside leak detection are implemented on the valve which has a great impact on the safe operation of the plant [1]. While input and output pressure measurement using a pressure gauge, temperature change and the humidity measurement, and pressure-resistant test are used for the valve leak detection, there are many problems such as the difficulty of the real time measurement at the minute leak situation, complexity of the pressure gauge correction and the process of the pressure measurement, and the reliability of the measured value. Therefore, it is necessary to develop the valve leak detection system using the acoustic emission (AE) method which is fast and accurate, and allows the real time measurement and evaluation of the minute leak situation. The valve leak detection method using the AE method is a convenient way to detect the sound of the leak outside the valve in case of existing leak inside of the valve, and the research is in progress recently to apply the method to the power plant valve [2,3].

2. Experimental Procedure

2.1 Test Valve

A test valve is 2 inch gate valve operated by motor as condition of high temperature and high differential pressure to feed condensing water of steam exhausted from turbine system in secondary system of nuclear power plant. The differential pressures across the valve were in the range of about 2~10 bar. Table I is a specification of the test valve. Besides the output current, the MATLAB detector code calculates the detector capacitance. The calculated output current is the input for the rest of the detector channel and the detector capacitance is an important input parameter.

2.2 Experimental Method

Fig. 1 shows the valve leak test apparatus. N_2 gas was pressured and passed through the valve, and released in the air. Acoustic sound was assured at the valve sheet and detected by two kinds of AE sensor. Alumina protection plate is impedance matching layer between the measured material and piezoelectric ceramics of AE sensor, and it transfers well and protects piezoelectric ceramics mechanically [4]. Output response was amplified by preamplifier to 20 dB. The leak status was simulated by the crack at the valve disk in which the crack was made by 3.0 mm thick. The pressure of the valve entrance was varied 2, 6, 10 bar.

Table I: Specifications of the test valve

Specification	
Valve Type	Motor Operated Gate Valve
Valve Name	PWR High-temp. Turbine
Valve Size(inch)	Steam Exhaust Valve
Max. Pressure(LB)	2
Operating Pressure(bar)	900
Operating	12.5
Temperature(° C)	310
Fluid	Steam
Valve Material	A217WC9

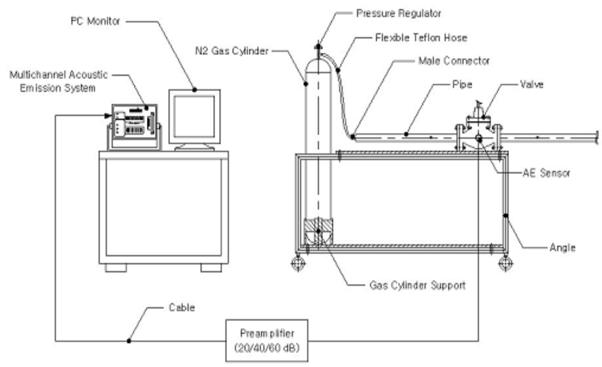


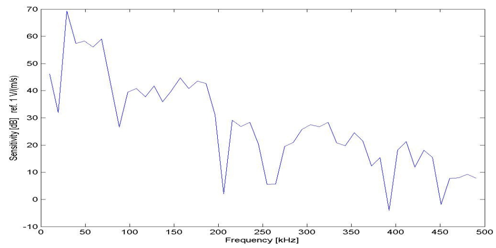
Fig.1. Experimental apparatus of the valve leak test.

2.3 Results and Discussion

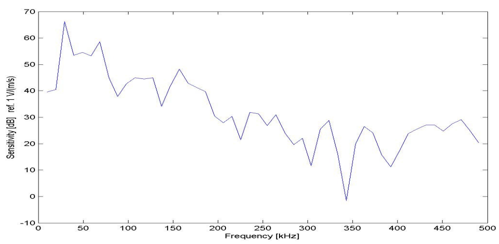
Fig. 2 shows sensitivity waveform processed from theoretical velocity of elastic source and voltage response of AE sensor by MATLAB program. At Fig. 2(a), peak sensitivity frequency and sensitivity of PZT AE sensor were 29.4 kHz, 69.3 dB, respectively. At Fig. 2(b), peak sensitivity frequency and sensitivity of the lead free AE sensor were 29.4 kHz, 66.3 dB, respectively. The peak sensitivity frequency of PZT and lead free AE sensor were same, since peak sensitivity frequency of AE sensor was determined by the ceramic size. The sensitivity of lead free AE sensor was lower than that of PZT by 3 dB and this was similar to k_{eff} of AE sensor at Table Π.

Table II: Piezoelectric properties of AE sensor

AE sensor	Fr[kHz]	Fa[kHz]	Δf[kHz]	keff
PZT	105.78	109.18	3.40	0.25
Lead free	158.32	161.80	3.48	0.21



(a) PZT



(b) Pb-Free

Fig. 2. Sensitivity waveform of AE sensor.

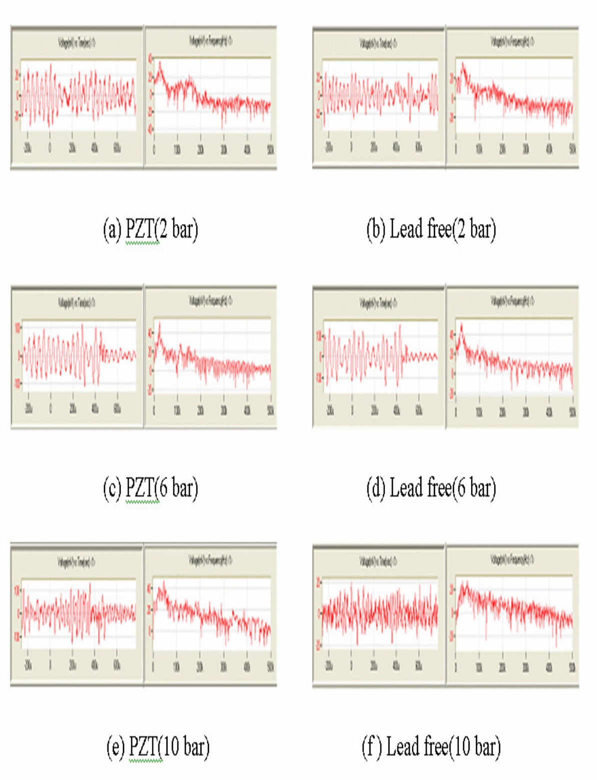


Fig. 3. Voltage and FFT waveform of the leak detection test.

Fig. 3 shows the voltage waveform and the FFT frequency response waveform detected at the 3.0 mm cracked valve disk. There were typical continuous type voltage signals by the flux leak at the power plant valve. The peak frequency was 25 kHz between 2 and 6 bar and increased to 50 kHz at 10 bar. From the results, it was concluded that the peak frequency was proportional to the pressure. The voltage amplitude of Y axis was about 40 mV and wasn't changed. The voltage waveform and FFT frequency waveform of PZT AE sensor were similar to those of the lead free AE sensor.

3. Conclusions

Piezoelectric and sensitivity characteristics of them were measured, and the leak detection at the cracked valve was tested with AE sensor. The results obtained from the experiments are as follows. Piezoelectric characteristics kp, d_{33} and g_{33} of lead free $[Li_{0.04}(Na_{0.54}K_{0.46})_{0.96}(Nb_{0.86}Ta_{0.1}Sb_{0.04})]O_3+0.1wt\%K_2CO_3$ piezoelectric ceramics were 0.49, 300 pC/N, 27.02 mV·m/N, respectively. Sensitivity of PZT and the lead free AE sensor were 69.3 dB and 66.3 dB, respectively, and the peak sensitivity frequency of them was 29.4 kHz. From the leak detection test, the peak frequency of PZT and lead free AE sensor were 25 kHz between 2 and 6 bar and increased to 50 kHz at 10 bar. The voltage amplitude of them was about 40 mV and wasn't changed. Therefore, it was concluded that lead free AE sensor can substitute for PZT AE sensor for the leak detection at the power plant valve.

REFERENCES

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