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Leak Evaluation for Power Plant Valve Using Multi-Measuring Method

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Abstract Condition based maintenance(CBM) for the preventive diagnosis of important equipments related to safety or accident in power plant is essential by using the suitable methods based on actual power plant conditions. To improve the reliability and accuracy of the measured value at the minute leak situation, and also to monitor continuously internal leak condition of power plant valve, the development of a diagnosis and monitoring technique using multi-measuring method should be performed urgently. This study was conducted to estimate the feasibility of multi-measuring method using three different methods such as acoustic emission(AE) method, thermal image measurement and temperature difference(ΔT) measurement that are applicable to internal leak diagnosis for the power plant valve. From the experimental results, it was suggested that the multi-measuring method could be an effective way to precisely diagnose and evaluate internal leak situation of valve.

Keywords: Gate Valve, Internal Leak, Multi-Measuring Method, Acoustic Emission(AE), Thermal Image Measurement, Temperature Difference Measurement

1. Introduction

Various types of valve have been used in power plant, and operation test and valve leak test are performed for valves influenced on the operational safety of power plant. Most of valves in power plant are leaked and damaged due to the insert of foreign objects between valve body and seat which is a seal part, damage according to the frequent open and close of valve, and also flaws and fatigue crack in welding zone (Joseph, 1979). These leaks or damages which lead a tremendous loss and accident to power plant operation are caused to increase of fluid leak rate, pressure drop in valve inlet side, malfunction of cooling system, and emission of radiation object, etc. A solution is highly desirable for the reduction of energy efficiency and the operational safety due to the accidents related to major valve leak (Pollock and Hsu, 1982; Bently, 1983; Wood and Harris, 1984).

To prevent these leaks and damages in valve, conventional leak test methods such as fluid level measurement, pressure difference(pressure drop) and temperature variation measurement between inlet and outlet, pressure increase and decrease(vacuum) test, and humidity test, etc. have been used. But these methods are not an useful method to diagnose and monitor continuously internal leaks and damages because these method are not able to diagnose leak conditions of little fluid rate such as leak evaluation, leak rate, leak velocity and leak type etc., and also have such disadvantages as complex preparation, measurement procedures and too many control parameter, and a low reliability due to calibration problem of pressure gauge and indirect measurement (Wichmann and Phillips, 1984; Anon, 1986; Jaeil Hong et al., 2008).

To improve the reliability and accuracy of

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the measured value at the minute leak situation, and also to monitor continuously internal leak condition of power plant valve, the development of a diagnosis and monitoring technique using multi-measuring method should be performed urgently (Au-Yang, 1993). In this study, leak tests for a 50.8 mm gate steam valve using artificially fabricated leak paths and two differential pressures were performed in order to analyze AE properties, the variations of thermal image and temperature difference when leak arise from the inside of valve seat. As a result of leak test for specimens simulated leak situation using cracked valve seat, we conformed that all peak frequencies in case of leak conditions were moved in higher band than 25 kHz peak frequency band showed in case of not leaking, and that the voltage amplitude increased linearly in proportion to the increase of leak rate. The resulting values of peak frequency and amplitude versus increase of leak rate versus were the primary basis for determining the feasibility of quantifying leak situation acoustically. And also, variations of thermal image following to leak situation were observed clearly and could be compared with the results of temperature difference measurement obtained from valve body. The large amount of data attained also allowed a favorable investigation of the effects of various different leak paths, leak rates and pressure differentials using multi-measuring method.

2. Experimental Procedure

2.1. Test Valve

A test valve is the high temperature turbine steam dump gate valve of 50.8 mm nominal size operated by motor and operated as condition of high temperature(310℃) and high differential pressure (125 bar). Specifications and type of the control valve used in this study is explained in Table 1. This valve is operated to pass condensed water generated from turbine to condenser system in secondary system of nuclear power plant. Fig. 1 shows a typical wedge type gate valve used in power plants, and also Fig. 2 shows a configuration of AE system, AE sensor attachment method and photo of test valve used in this study. In Fig. 1, symbol "I" means fluid inlet side of the test valve and symbol "O" means fluid outlet side of the test valve, respectively.

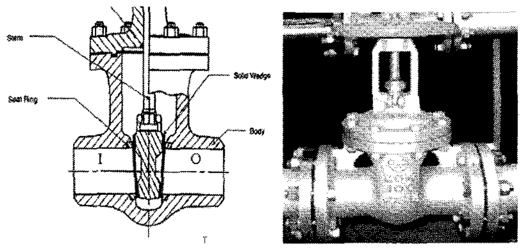


Fig. 1 Typical wedge type gate valve

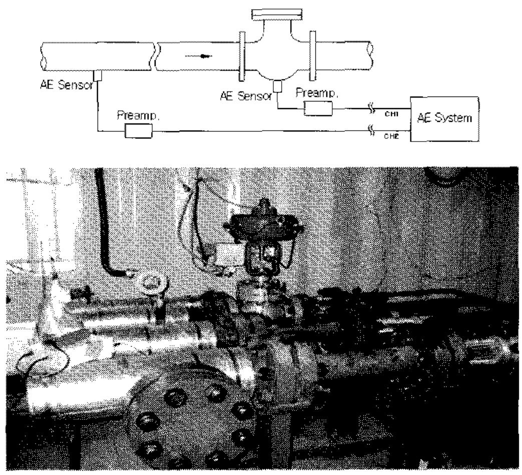


Fig. 2 Configuration of AE system, AE sensor attachment method and photo of test valve

Table 1 Specifications and type of the control valve

Valve name	Steam dump valve
System	HP turbine steam line
Valve size	50.8 mm
Valve type	Gate
Operating pressure	125 bar
Operating temperature	310 ℃
Material	A217WC9
Pressure class	900 LB

2.2. Experimental Method

Fig. 3 shows a high temperature and pressure fluid leak simulated test loop. Leak tests were performed on a gate valve attached test loop system in operating using portable AE leak detector, temperature measuring system and thermal image measuring system. All tests were performed as condition of operating valve in actual power plant. Infrared thermometer emitted regular infrared wavelengths was used for the temperature difference measuring in valve. Measuring range of the infrared thermometer is from -30 to 900 ℃ and it has resolution up to 0.1 ℃ and accuracy of ± 2 ℃ or ± 0.75 % of reading. In order to raise reliability of the measurement, temperature sensors were located on pipeline and valve at a distance of the length in proportion to pipeline diameter(D). Using temperature sensor of locations showed in Fig. 4, temperature difference(ΔT) was measured. In Fig. 2, 2D, 3D and 4D mean positions corresponded to 2, 3 and 4 times of length of pipeline diameter to the fluid inlet direction from the center line of valve body 1 and 2, and also 2D-1, 3D-1 and 4D-1 mean positions corresponded to 2, 3 and 4 times of length of pipeline diameter to the fluid outlet direction, respectively.

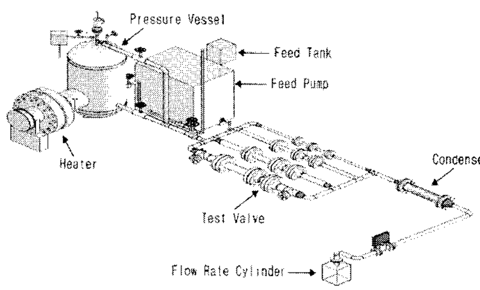


Fig. 3 High temperature fluid loop system

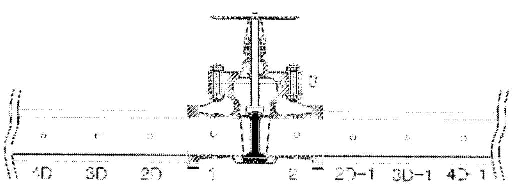


Fig. 4 Point of ΔT leak diagnosis

Table 2 Specifications of AE measuring instrument

Instruments	Type and specifications
AE sensor	Resonance frequency : 143 ㎑
Pre-amplifier	Frequency band : 20 ㎑~2 ㎒
	Gain : 20, 40, 60 dB selectable
Local processor	Frequency range : 1~400 ㎑
Main-amplifier	Main gain : 20 dB

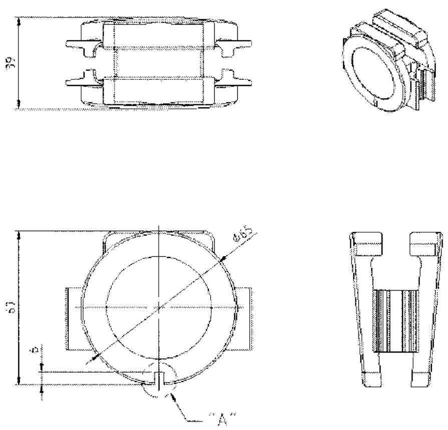


Fig. 5 Shape of valve disc and seat

AE signal radiated from the leak in valves is detected using AE sensor attached on surface of valve body. The output signals from the sensor were fed into a portable AE leak detector. Table 2 shows specifications of AE measuring instrument. A valve leak tests to simulate leak situation on the valve seat side were performed by manufacturing crack in valve disc and leak rate was regulated by controlling the inlet pressure considering that leak rate varies by both a leak path size and differential pressure worked at the disc in valve. Valve inlet pressures were varied by two types of 20 and 40 bar, and crack on the disc was manufactured to 6 mm depth crack of V-notch type in the direction of seat ("A" in Fig. 5) using a cutting bite. Crack width of V-notch was varied to two types of 0 mm (valve close condition) and 0.5 mm size. Fig. 5 shows disc and seat type of test valve and position of notch manufactured. Measuring range of the thermal image camera is from -40 to 2,000 ℃ and it has resolution up to 0.03 ℃ and accuracy of ± 2 ℃ or ± 2 % of reading.

Table 3 Specifications of ΔT measuring instrument

	Specification
Model	Testo 860
Range	-30 ~ + 900 ℃
Accuracy	± 0.75 %, ± 2 ℃
Resolving power	0.1 ℃
Test method	Infrared light

Table 4 Specifications of thermal image camera

		TH9100PRO
Measuring range	Range 1 Range 2 Range 3	-40 to 120 ℃ 0 to 500 ℃ 200 to 2000 ℃
Resolution	Range 1	0.08 ℃, 0.03 ℃
Accuracy	± 2 ℃ or ± 2 % of reading whichever greater	
Pixels	0.41 Mega	
Effective image	752 (H) x 480 (V) Pixels	
Field of view	30.1° (H) x 22.7 ° (V)	
Sensitivity	1 Lux	
Focusing distance	30 cm to infinity	
Auto exposure	Provided	
Video signal	NTSC/PAL	

Table 5 Temperature difference measurement results of test valve

Temperature(℃)					
1	2	3	2D	3D	4D
			2D-1	3D-1	4D-1
110.2	133.8	99.6	52.7	48.8	48.6
		54.8	52.1	48.7	48.5
101.9	82.1	155.6	57.3	52.6	60.6
		50.2	53.0	43.5	46.6

3. Results and Discussion

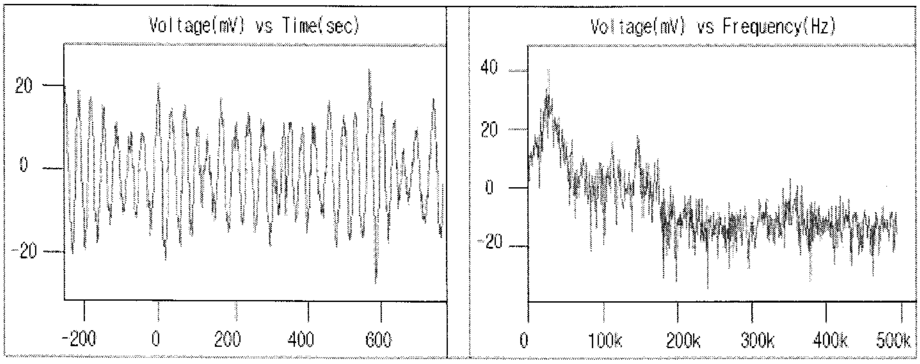
3.1. AE Measurement

Fig. 6 shows voltage and FFT frequency waveform obtained from AE measurement using piezoelectric acoustic emission sensor for steam valve leak test according to inlet pressures of 20 and 40 bar, and leak conditions in the case of disc crack width of 0.5 mm. From the voltage waveform versus time elapsed in Fig. 6(a), (b), (c) and (d), it can be seen that continuous type signals show representatively. From the FFT waveforms versus time elapsed in Fig. 6, it can be seen that peak frequencies for all pressure conditions show in about around 25 kHz regardless of pressure increase. And also, it was conformed that all peak frequencies in case of leak conditions were moved in higher band than 25 kHz peak frequency band showed in case of not leaking, and that the voltage amplitude increased linearly in proportion to the increase of leak rate. In Fig. 6, the amplitude of voltage increased from 40 mV to 60 mV.

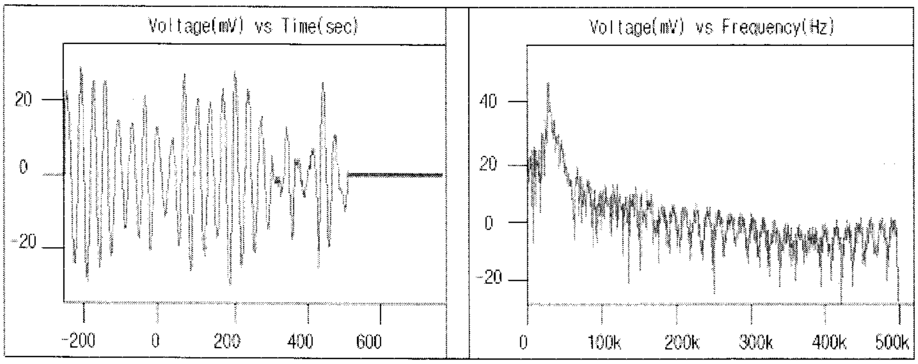
3.2. Temperature Difference Measurement

Surface temperatures on the test valve body and pipelines during leaking in valve contained notch crack of 0.5 mm width in disc were measured for temperature distribution measurement of valve components. Temperature distribution measurement was performed both in the position of equivalent to length of 2, 3 and 4 times of pipeline diameter in the fluid inlet direction centering around valve body, and in the position of equivalent to length of 2, 3 and 4 times of pipeline diameter in the fluid outlet direction centering around valve body, respectively.

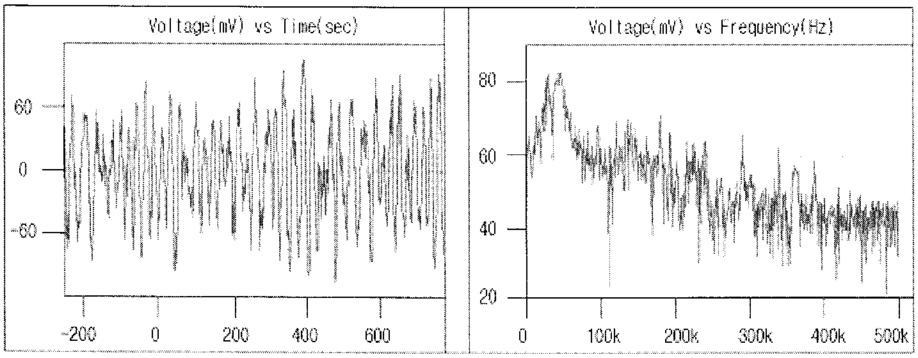
Table 5 shows temperature difference measurement results of test valve in the condition of leak under the pressure of 40 bar. From the twice measuring results obtained at both the number 1 position(valve inlet side, "I" in Fig. 1) and number 2 position(valve outlet side, "O" in Fig. 1) on the valve body, it could be seen that the temperature(133.8 ℃) of the number 2 position in outlet side is higher than one(110.2 ℃) of the number 1 position at the first measurement, and temperature(101.9 ℃) of the number 1 position in inlet side are higher than one(82.1 ℃) of the number 2 in outlet side at the second measurement. And also, it can be seen that the temperature(99.6 ℃) of the number 3 in inlet side of flange is higher than one(54.8 ℃) of



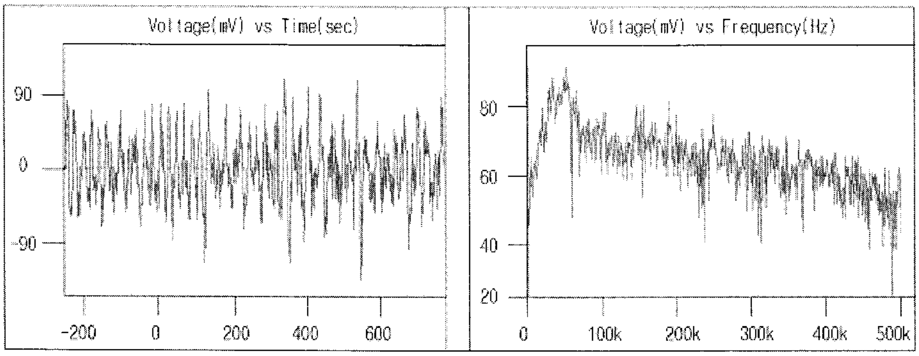
(a) 0 mm, 20 bar no leak



(b) 0 mm, 40 bar no leak



(c) 0.5 mm, 20 bar leak



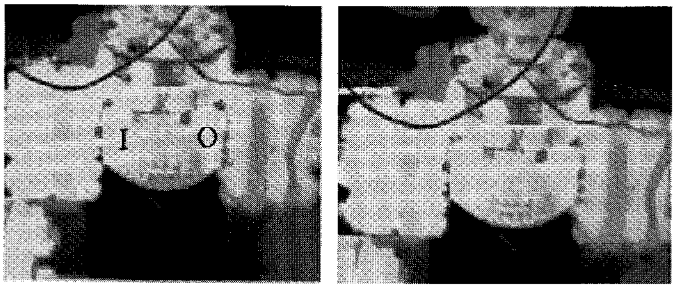
(d) 0.5 mm, 40 bar leak

Fig. 6 Voltage and FFT waveform analysis outlet side. From these results, we are conformed that temperature differences due to the irregular fluctuation of high temperature fluids and fluid moving varies continuously, and these irregular temperature distribution was the same as the results of temperature measurement for valves operated in actual power plant.

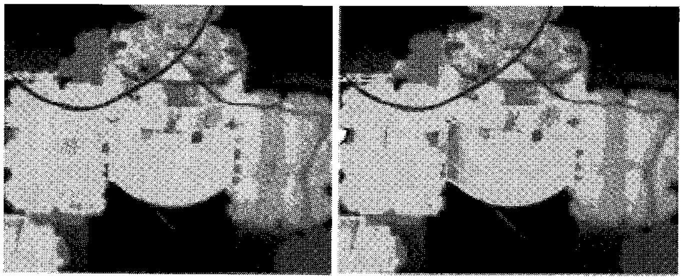
3.3. Thermal Image Measurement

Fig. 7 shows a representative thermal image taken for thermal distribution measurement of the test valve using a thermal image camera during leaking in valve contained notch crack of 0.5 mm width in disc. Fig. 7(a) shows the valve surface thermal images in the condition of no leak under the pressure of 20 and 40 bar, respectively. It can be seen that there is no leak symptom in the test valve at present because of having not disc crack which means valve closing condition. Symbol I and O in the left photograph of Fig. 7(a) means valve inlet side and valve outlet side of valve body, respectively.

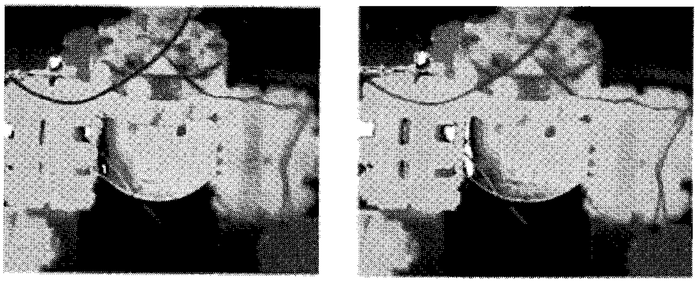
Fig. 7(b) shows thermal images for the test valve contained notch crack of 0.5 mm width after a leak test lapse of about 10 seconds which is in the condition of initial leak stage. As shown in this figure, we conformed that blue color images were changed into yellow color image from comparing with the results of Fig. 7(a). And also we conformed that yellow color images were changed into red color image and



(a) 0 mm, 20 bar(left) and 40 bar(right) no leak



(b) 0.5 mm, 20 bar(left) and 40 bar(right), initial leak



(c) 0.5 mm, 20 bar(left) and 40 bar(right), leak in progress

Fig. 7 Thermal images of test valve

the intensity of yellow color image increased linearly in proportion to the increase of differential pressure.

Fig. 7(c) represents thermal images for the test valve contained notch crack of 0.5 mm width after a leak test lapse of about 30 seconds which is in the condition of leak increasing stage. As shown in this figure, we conformed that yellow color images were changed into red color image from comparison with the results of Fig. 7(b). And also we conformed that yellow color images were changed into red color image and all intensity of yellow and red color image increased linearly in proportion to the increase of differential pressure. From the results of thermal images of Fig. 7, we conformed that thermal image measurement method is an effective method and could evaluate leak stage and degree from the evaluation on appearance· and color intensity of yellow and red color image. It is considered that heat of high temperature steam passing through cracked disc was transmitted on surface of valve body quickly after a leak test lapse of about 10 seconds which is in the condition of initial leak stage.

Compared the thermal image measuring results with temperature difference measuring results in Table 5, temperature measured using temperature difference(ΔT) measurement from inlet position 1 [("I" position in the Fig. 7(a)] and outlet position 2 ["O" position in the Fig. 7(a)] are 110.2 ℃ and 133.8 ℃ at the first temperature measurement and also 101.9 ℃ and 82.1 ℃ at the second temperature measurement respectively, but on the other hand displayed image temperature measured from inlet position 1 and outlet position 2 using thermal image measurement method are 90 ℃ and 130 ℃ at both conditions of the first and the second measurement, respectively. The final result of temperature measurements on inlet position 1 and outlet position 2 through the evaluation of temperature measurement of 3 times above was consistent with the results of both thermal image measurement and the second measurement values by temperature difference measurement.

Therefore, it was concluded that the results of the temperature difference measurement show irregular temperature values and the results of the thermal image measurement show correct values in the same leak condition, and also it is suggested that multi-measuring methods should be applied in addition to temperature difference measurement method considering that only single method by temperature difference measurement may be difficult to evaluate for diagnosis results following to operating condition of power plant.

4. Summary

Using a combination of acoustic emission method, temperature difference and thermal image measurement, it is possible to precisely evaluate both the leak existence and the leak degree. Acoustic emission method is a powerful method for incipient leak detection and also two methods of temperature difference method and thermal image measurement are useful to quickly detect leaking valves and evaluate quantitatively leak conditions comparing with results obtained from these two methods. Measuring uncertainties should be eliminated by multi-measuring methods through the precise analysis performance, above all, it is recommended that the preceding of understanding and analyzing for valve system in actual power plant is essential and database should be established finally through a repeated in-situ valve leak test. From experimental results in this study, it was suggested that data obtained from these results could be applied hereafter for judgment for the leak existence and prevention of fluids leak loss in power valves. The outcome of the study can be definitely applied as a means of the diagnosis or monitoring system for energy saving and prevention of accident for power plant valve. And also, essential technology can be transferred to domestic company wanted to merchandise and applied to a succeeding research program for leak monitoring of pressure vessel, pipeline and fuel channel in heavy water nuclear power plant, etc. It would hopefully be an opportunity for AE to be recognize as the efficient technique for on-line monitoring or precise diagnosis for valve in power plant.

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