



## **Condition Monitoring of a Check Valve for Nuclear Power Plants by Means of Acoustic Emission Technique**

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### **ABSTRACT**

The primary object of this work is to investigate advanced condition monitoring systems based on acoustic emission detection that can provide timely detection of check valve degradation and service aging so that maintenance/replacement could be performed prior to loss of safety function. The research is focused on the capability of AE technique to provide diagnostic information useful in determining check valve aging and degradation, check valve failures and undesirable operating modes. The systematic approach to classify the dynamic responses of AE signatures associated with typical failure modes of check valve for nuclear power plants(NPPs) is performed in this study. The characteristics of AE signature responses of internal parts of check valves due to local aging and degradation is analyzed by extracting effective AE parameters .

This work also includes the investigation and adaptation of several advanced sensor technologies such as accelerometer and advanced ultrasonic technique. In addition, this work will develop advanced sophisticated signal processing, noise reduction, and pattern recognition techniques and algorithms from check valve degradation.

**KEY WORDS** : On-Line monitoring, check valve, degradation, maintenance, replacement, safety function, AE technique, accelerometer, ultrasonic technique, pattern recognition

### **INTRODUCTION**

In support of the International Nuclear Energy Research Initiative(INERI) program, which is to develop and demonstrate advanced sensor and computational technology for on-line monitoring of the condition of components, structures, and systems in advanced and next-generation nuclear power plants. The check valve is one of typical components being used extensively in safety systems of nuclear power plants. The failure of check valves have resulted in significant maintenance efforts and , on occasion, have resulted in water hammer, over-pressurization of low-pressure systems, and damage to flow system components. These failures have largely been attributed to severe degradation of internal parts such as hinge pin, arms, discs, and disc nut pins resulting from instability of check valve discs under normal plant operating conditions. Acoustic emission(AE) [1] is the pressure wave generated from the phenomenon of transient elastic waves by a variety of sources. Particular interest are those generated either when solids contact each other or when liquids flow through pipes and fittings.

The primary objective of this work is to demonstrate condition-monitoring system based on acoustic emission detection that can provide timely detection of check valve degradation and service aging so that maintenance/replacement could be preformed prior to loss of safety function. For this purpose, the work is focused on the capability of AE technique to provide diagnostic information useful in determining check valve aging and degradation, check valve failures and undesirable operating modes. This work also includes the investigation of applicability of several the other sensor technologies such as accelerometer and advanced ultrasonic technique for diagnostic tool for check valves.

The systematic approach to classify the dynamic responses of AE signatures associated with typical failure mode of check valve is performed in this study. The characteristic of AE signature responses of internal parts of check valves due to local aging and degradation is analyzed by extracting effective AE parameters. In addition, classified condition monitoring technique of check valve is introduced specific signal process on the basis of noise filtering technique, such as pattern recognition, and neural network schemes.

To get the basis data of the typical wearing for the systematic signature analyses to match the selected wearing patterns of internal parts with their different modes, condition monitoring tests will be performed with the test loop. The AE test on check valves was performed jointly with Korea Atomic Energy Research Institute(KAERI). This is an introduction to some part of work in progress for obtaining the characteristic signatures of the typical wearing of check valve from test loop to match the selected wearing patterns of internal parts with their different modes.

## **INTEREST IN CHECK VALVES**

Check valves are used extensively in nuclear plant safely systems. The failures of these valves have resulted in significant maintenance efforts and, on occasion, have resulted in water hammer [2], over-pressurization of low-pressure systems, and damage to flow system components. These failures have largely been attributed to severe degradation of internal parts, such as hinge pins, hinge arms, discs, and disc nut pins, resulting from instability of check valve discs under normal plant operating condition. Check valve instability may be a result of misapplication and may be exacerbated by low-flow conditions and up stream flow disturbances [3,4].

Although there are many possible failure mechanism for check valve, the most common problem are due to system flow oscillations or system piping vibrations that induce check valve component wear, and often component failure. Most failures induce additional vibration from the valve body. The most common types of physical damage in check valves are disk separated from the hinge pin, stud pin broken, disk nut loose, disk partially open, disc caught on inside of the seat ring, cracked disk, worn hinge pin, and bent hinge pin, disk, or hinge arm. Among these faults, we take specially interest in disk and hinge pin wear.

However, most of these faults cause sounds detectable by monitoring acoustic emission from the valve body. Inappropriate movement of disk can be detected by ultrasonic measurements or through motion (usually acceleration) sensors attached to the body of the valve. The generally accepted method of assuring operability has been to disassembly the check valve during a shutdown and inspect the valve's internal components. Unfortunately, this procedure is expensive in terms of manpower and time. Therefore, it is important to develop and demonstrate advanced sensor and computational technology for on-line monitoring of the condition of check valve.

In this study, we will provide an evaluation of the characteristics of advanced fusion sensors. Fusion sensors combine the signals from different types of sensors and are applied to extend the measurement range, accuracy or application of what is possible with a single type of sensor. Fusion sensors also have the potential to reduce the noise and uncertainties of signal origin, or data association, for single sensors. Advanced fusion sensors integrated with acoustic emission, accelerometer and ultrasonic sensors can be applied for condition monitoring of components like check valves. To get baseline data from these typical wearing, condition monitoring tests will be performed with the DVI test loop at KAERI with selected wearing such as disk/seat wear, hinge/busing wear, and foreign object interference. Figure 1 shows the swing type check valve.

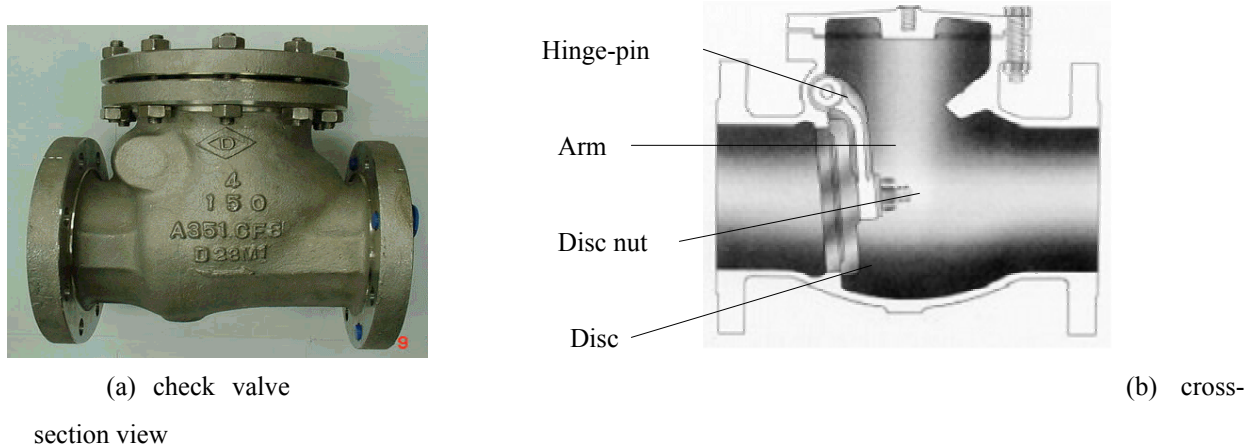


Fig. 1 Swing type check valve

## CONDITION MONITORING METHOD OF CHECK VALVE

The Primary object of this work is to identify and recommend methods of inspection, surveillance, and monitoring that would provide timely detection of valve degradation and service wear so that maintenance or replacement could be performed prior to loss of safety functions. We will carry out an evaluation of several developmental and commercially available check valve diagnostic monitoring methods, in particular, those based on measurements of acoustic emission, ultrasonic, and accelerometer. That is, the methodology employed by this work is basically a three monitoring approach.

In DVI (Direct Vessel Injection) test loop, a check valve is installed to prevent the reverse flow from the high pressurized area(primary system) to the low pressurized area. The check valves can experience local degradation under operation in a number of ways. In this study, three different sensors, ultrasonic device, acoustic emission sensor, and accelerometer, were chosen to record condition-monitoring signals of a selected check valve.

### Acoustic Emission Monitoring

Acoustic emission is detected by sensors, such as piezoelectric-type accelerometers or microphones, which respond to pressure waves over a wide range of frequencies. Analyses of acoustic emission signals obtained from check valves can be used to monitor check valve disc position, movement, and mechanical condition, as well as internal flow/leakage through the valve. Various methods of obtaining and analyzing data are available. These include filtering, fast Fourier transform (FFT), and computer analysis such as pattern recognition technique.

In this work, acoustic emission monitoring will be used to detect check valve disc movement and to evaluate valve degradation such as disk/seat and hinge pin wear. We are also carry out check valve acoustic emission testing under controlled flow loop conditions and with the introduction of various implanted defects that simulated severe aging and service wear. The check valve monitoring by acoustic emission carry out as following check valve operational conditions.

- \* Valve with new and artificially worn disk (0, 25, 50, 70%)
- \* Valve with new and artificially worn hinge pin (0, 25, 50, 70%)
- \* Valve with artificially leakage (0, 25, 50, 70%)
- \* Loop condition (steady stat, transient operation 0, 3, 6, 9bar)

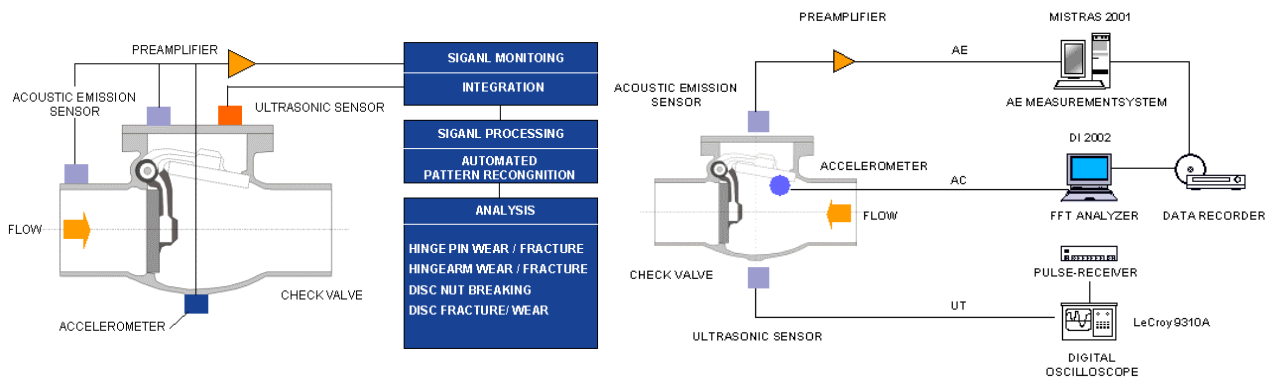


Fig. 2. The schematic diagram for condition monitoring of the check valve

A schematic diagram of the installation shows in Fig. 2. The acoustic emission signals are detected with AE sensors attached to the center of the check valve. These AE signals detected from the sensor are amplified by a preamplifier, which had a fixed gain of 40dB. After passing through a band pass filter of 100-1200kHz, to remove the electrical and mechanical background noise, the signals are by the main amplifier (40dB). The AE parameters, such as AE events, amplitude, and the duration time of signals, are analyzed in the AE system (MISTRAS 2001). In addition, a digital oscilloscope (LeCroy 9310A) is used to analyze the AE signal waveform. AE data also will be collected and compared form different sensors, such as accelerometer, ultrasonic, and different operating conditions.

### Ultrasonic Monitoring

Ultrasonic measurement involves the introduction of high-frequency sound wave into a part being examined and an analysis of the characteristics of the reflected beam. Typically, one or two ultrasonic transducers are used which provide both transmission and receiving capabilities. The ultrasonic signal is injected from outside the valve be the transmitting transducer and passes through the valve body, where, it is reflected by an internal part such as disc, hinge arm back toward receiving transducer.

Usually, ultrasonic technique can used to produce a time waveform display from which disc position and movement may be easily determined. And also it can be used to detect a missing or stuck disc. For example, if the disc is missing, no signal will be reflected from the disc. Therefore, disc stud wear can be detected by ultrasonic technique by monitoring the motion of both the disc and hinge arm using ultrasonic transducers.

### Accelerometer Monitoring

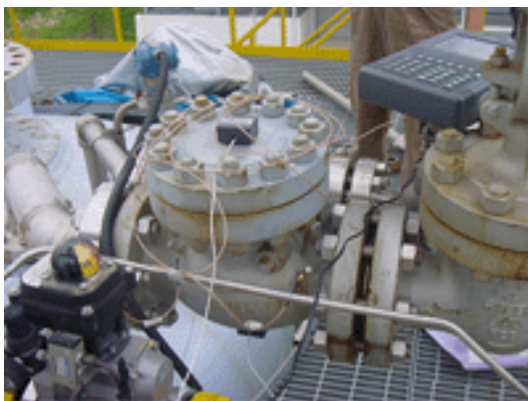
Several condition monitoring tests is carried out on an 4 or 8-in check valve in new condition and with simulated degradation. In particular, vibration signal are detected by sensors, such as accelerometers or microphones, which respond to pressure waves over a low-frequency range(<100khz). Accelerometers are strapped to the body of check valves in a manner shown in Fig. 2. A check valve methodology combines acoustic emission monitoring with either ultrasonic and accelerometers.

### EXPERIMENTAL SETUP

In this study, we provided an evaluation of the characteristics of advanced fusion sensors. Fusion sensors combine the signals from different types of sensors and are applied to extend the measurement range, accuracy or application of what is possible with a single type of sensor. Fusion sensors also have the potential to reduce the noise and uncertainties of signal origin, or data association, for single sensors. Advanced fusion sensors integrated with acoustic emission, accelerometer and ultrasonic sensors can be applied for condition monitoring of components like check valves.

To get baseline data from these typical wearing, condition monitoring the first experiment was performed with the DVI test loop at Korean Atomic Energy Research Institute (KAERI) and the second one was performed with the modified DVI test loop. Figure 3 shows the photograph representation of the installation for condition monitoring.

The purpose of this experiment is chiefly to collect baseline data that measured background noise level and leakage level of field for swing type check valve. This experiment performed three parts such as acoustic emission, ultrasonic, and accelerometer. Compared with vibration monitoring, which involves the detection of elastic wave at audio frequency (low frequency), the AE technique involves the detection of elastic waves at ultrasonic frequency (high frequency).



(a) DVI test loop



(b) modified DVI test loop

Fig. 3 The photograph of check valve in DVI test loop (KAERI)

The acoustic emission signals are detected with AE sensors attached to the center of the check valve. These AE signals detected from the sensor are amplified by a preamplifier, which had a fixed gain of 40dB. After passing through a band pass filter of 100-1200kHz, to remove the electrical and mechanical background noise, the signals are by the

main amplifier (40dB). The AE parameters, such as AE events, amplitude, and the duration time of signals, are analyzed in the AE system (MISTRAS 2001). In addition, a digital oscilloscope (LeCroy 9310A) is used to analyze the AE signal waveform. AE data also will be collected and compared form different sensors, such as accelerometer, ultrasonic, and different operating conditions. Figure 2 shows the schematic diagram of the installation for condition monitoring. Accelerometers were strapped to the body of check valve in a manner shown in Fig. 2. In addition, ultrasonic transducer (UT,1MHz) was attached to the bottom of body of check valve. Figure 3 shows the photograph representation of the condition monitoring.

## EXPERIMENTAL RESULTS AND DISCUSSION

Figure 4 shows the typical AE waveform and its corresponding spectra obtained from initial background noise. As shown in Fig. 4, FFT of detected AE signal is concentrated in the range of 100–500 kHz. Figure 5 shows the waveform and its corresponding spectra of the accelerometer output for the background noise. The resulting accelerometer signature shows that the FFT is concentrated in the range of 1.2, 2 and 2.7 kHz.

The typical AE waveform and the corresponding spectra obtained from leak flow signal of check valve B which has a size of approximately 0.1mm in diameter is shown in Fig.6(a) and (b), respectively. As shown in Fig. 6, leak in check valve can be clearly detected by comparing the obtained waveform and spectra between normal and leak check valves. Figure 7 shows the typical accelerometer waveform and corresponding spectra obtained leak valve which has leak size of 0.1mm in diameter. As shown in Fig. 6 and Fig. 7, the characteristic of leak signals obtained from both AE sensor and accelerometer indicates higher increase of voltage in waveform and rapid decrease of amplitude in FFT spectrum.

Typical oscillogram of two traces (open, close) captured by the UT sensors at disk of check valve during operation is demonstrated in Fig. 8(a) and (b), respectively. It is shown in Fig. 8 that UT sensor provides effective detection of disk of check valve by observing time domain UT signal.

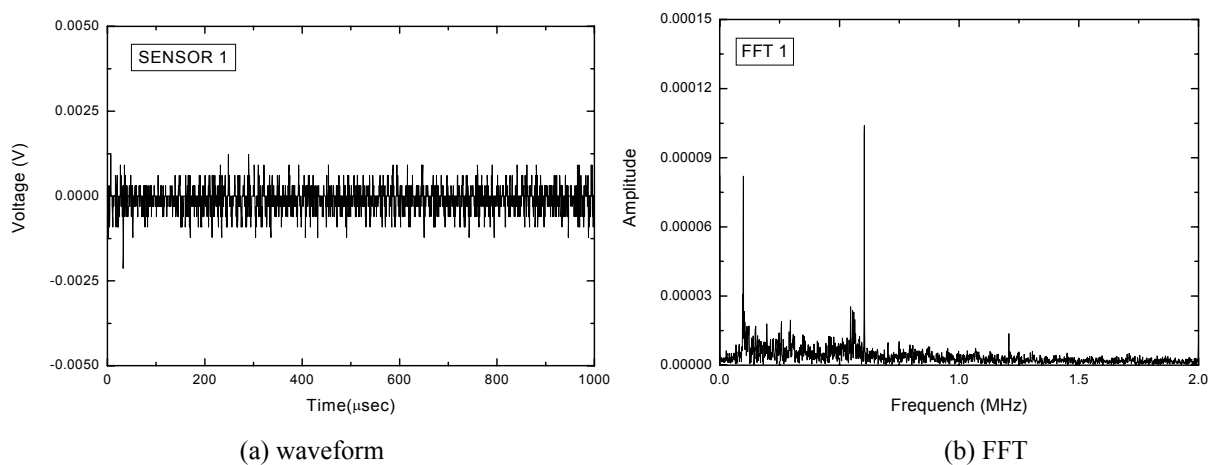
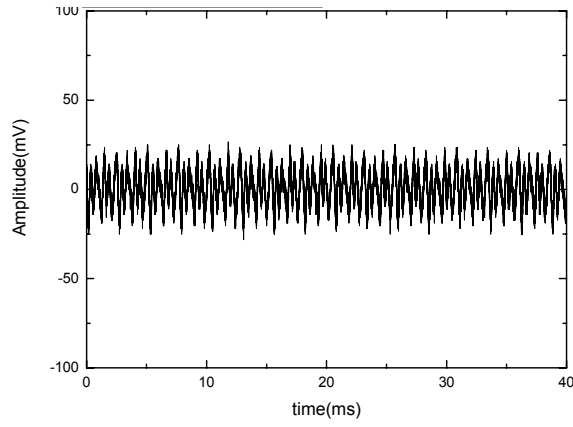
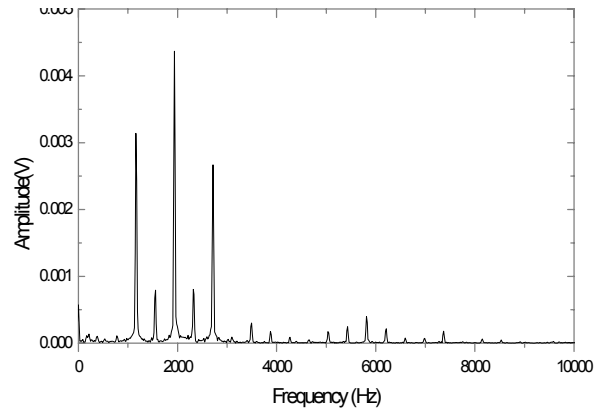


Fig. 4 The AE waveform and corresponding spectra obtained background noise.

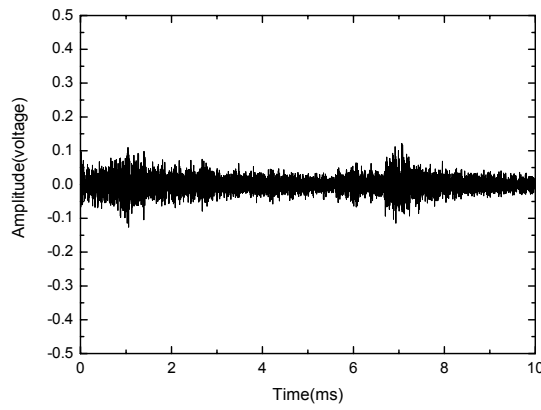


(a) waveform

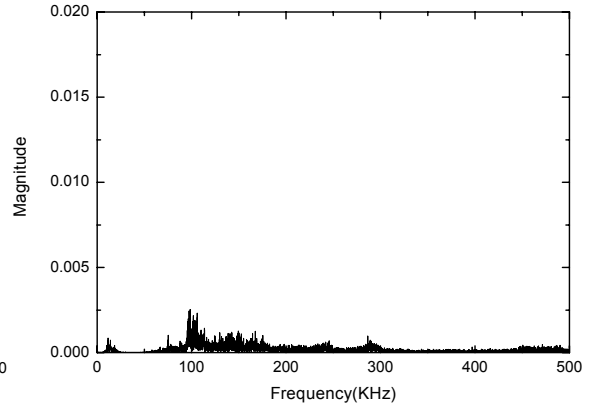


(b) FFT

Fig. 5 The accelerometer waveform and corresponding spectra obtained background noise.

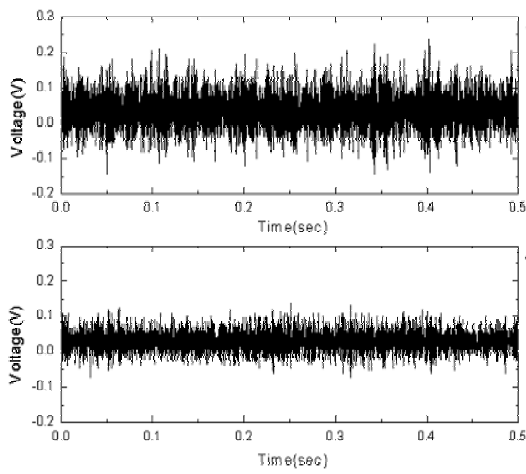


(a) waveform

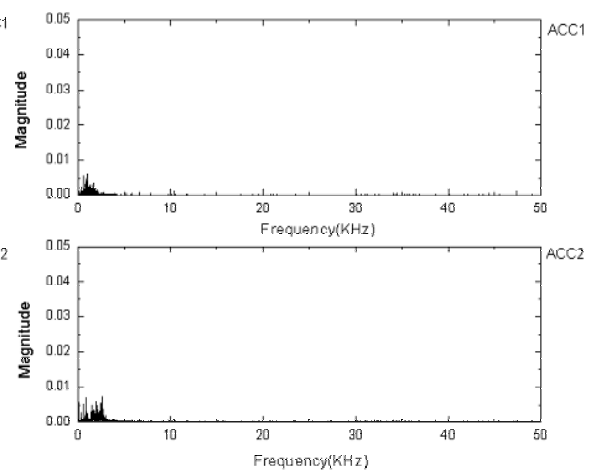


(b) FFT

Fig. 6 The AE waveform and corresponding spectra obtained leak valve.



(a) waveform



(b) FFT

Fig. 7 The accelerometer waveform and corresponding spectra obtained leak valve.

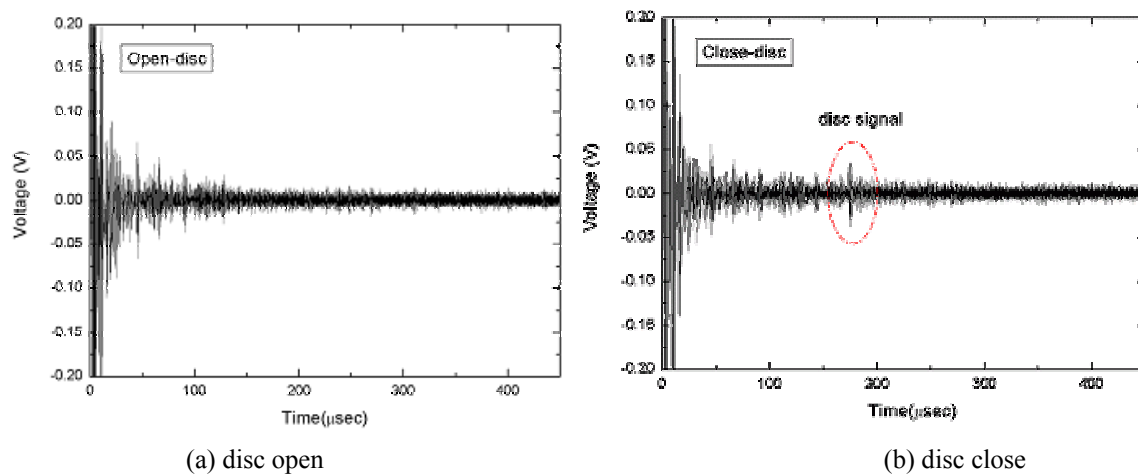


Fig. 8 The UT signals obtained from disc of check valve

## CONCLUSIONS

The primary objective of this research is focused on capability of each sensor including AE, accelerometer, and UT to provide diagnostic information useful in determining check valve aging and service wear effects, check valve failures, and undesirable operating modes. In this work, as the first step, an application of acoustic emission sensor and accelerometer for on-line monitoring of condition of check valve was described. It was found that AE sensor and accelerometer could be used effectively for condition monitoring of leak test of check valve. It was demonstrated that the characteristic of leak signals obtained from both AE sensor and accelerometer indicates higher increase of voltage in waveform and rapid decrease of amplitude in FFT spectrum. In addition, ultrasonic sensor provided useful tool for detection of disk of check valve. We are now carrying out the test to investigate the characteristic of response of signature from each sensors associated with some more different failure modes of check valve by considering noise reduction, and pattern recognition techniques.

## ACKNOWLEDGEMENT

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