A Study of Condition Monitoring of Check Valve Using Acoustic Emission and Neural Network Technique

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1. Introduction

The check valve [1] is one of typical component being extensively used in safety systems of nuclear power plants. The failures of check valves have resulted in significant maintenance efforts, on occasion, have resulted in water hammer, over-pressurization of low-pressure systems, and damage to flow system components [2-3].
The objective of this research is to demonstrate condition-monitoring system based on acoustic emission, AE [4] 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. This work is also focused on the capability of neural network technique to provide diagnostic information useful in determining check valve aging and degradation, check valve failures and undesirable operating modes.

2. Methods and Results

2.1 Artificial Neural Network(ANN) Method

The ideal check valve monitoring system would involve the use of one or more sensors attached externally to the check valve. In this study, classical signal processing techniques and artificial neural networks (ANNs) computing have been integrated to identify leak signals associated with different faults [5]. That is, quantitative leak size was evaluated using artificial neural network technique with data obtained from leak signal in a different mode ('disc wear' and 'foreign object' failure mode). In this study, classical signal processing techniques and artificial neural networks computing have been integrated to identify waveforms associated with different faults. Time domain signals and frequency domain signals are used for the quantitative nondestructive evaluation utilizing a neural network in this research.

2.2 Acoustic Emission Method

In this study, the concept of condition monitoring of check valve is to utilize two or more of monitoring techniques. Several commercially available check valve diagnostic-monitoring methods were evaluated, especially for the techniques based on measurement of acoustic emission, ultrasonic, and accelerometer. The methodology employed by this work is basically a three monitoring approach. Figure 1 shows simplified depiction of condition monitoring for check valve. Basically, a three-monitoring approach such as acoustic emission, ultrasonic, and accelerometers was employed for this investigation.

2.3 Experimental Set-Up

AE testing was used to detect a disc movement and to evaluate valve degradation such as disc wear and foreign object. The AE testing for check valve under controlled flow loop conditions and with the introduction of various implanted defects that simulated severe aging and service wear was performed. In this study, we performed leak test with two different kind of valve degradation condition:

- Valve with new and artificially worn disk: reduction in diameter of the disc (1.0, 2.0 and 3.0mm round cutting)
- Valve with artificially leakage: foreign object interference (0.5, 1.0, 1.2, 1.5,2.0, 2.4mm welding rod)
- Loop condition (0, 3, 6, 9bar/ 1060, 1300 and 1700 rpm)

The AE signals are detected with AE sensors attached at the center of the check valve. These AE signals are amplified by a preamplifier, which had a fixed gain of 40dB. After passing through a band pass filter of 100 to 1200 kHz, to remove the electrical and mechanical background noise, the signals are amplified by the main amplifier (40dB). The AE parameters, such as AE r.m.s, energy, and frequency of AE signals, are analyzed in the AE system (MISTRAS 2001). In addition, a digital oscilloscope (LeCroy 9310A) is used to analyze the AE signal waveform. Also, AE data will be collected and compared with different sensors, such as accelerometer and ultrasonic and different operating conditions.

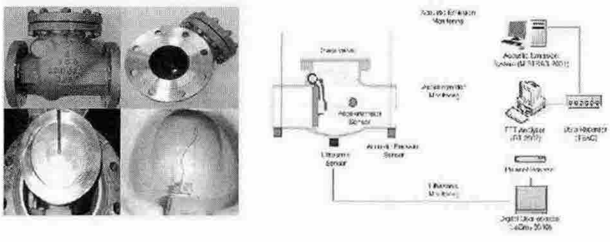


Figure 1. Specimen of check vale and schematic diagram of AE experimental set-up

2.4 Results

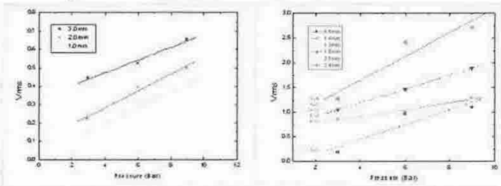
2.4.1 AE Signal Characteristics

Figure 2 shows the results of actual measurement for the comparison of intensity of AE r.m.s. value by a leak in the 'disc wear' and 'foreign object' failure mode. As shown in Figure 6, AE r.m.s increases as the pressure (or rpm) in the same leak size increase, and this is because leak rate increases as the pressure and leak size increases.

It is desirable to obtain some estimates of the flow rate for a leak. This information is difficult to obtain directly from acoustic intensity data because the amplitude of the acoustic signal varies with geometry and temperature for a given flow rate. Thus, other characteristics of the signals must be examined. One possible way is to monitor the variation in the r.m.s value with time.

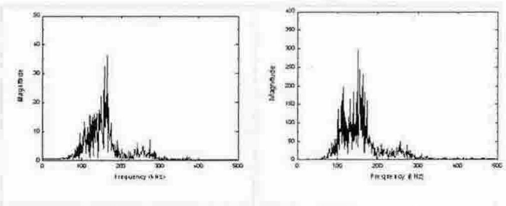
The frequency spectrum of the check valve leakage is illustrated in Fig.3. Figure 3 shows the frequency spectra of leak signals at 150 kHz sensor. As compared 'disc wear' with 'foreign object' failure mode, the frequency range of leak signals between 'disc wear' and 'foreign object' are significantly different.

2.4.2 Artificial Neural Network



(a) disc wear (b) foreign object

Figure 2. AE rms data obtained from 'disc wear' and 'foreign object' failure mode



(a) disc wear (b) foreign object

Figure 3. Frequency spectrum(FFT) obtained from 'disc wear' and 'foreign object' failure mode

For quantitative leak evaluation, we used only 6 features such as AE amplitude, rms., pressure, signal strength (or energy), and FFT information from collected two different failure modes of check valve as the input to the neural network.

Table 1 shows the neural network results obtained form 'disc wear' and 'foreign object' failure modes.

Features of 135 cases were used for training neural network and then features of 216 cases were used for testing trained neural network. As shown in results, maximum errors of 'disc wear' failure mode was just 26% but, errors of most cases were lower than 5%. In case of 'foreign object' failure mode, maximum error was about 27% but, errors of most cases were lower than 10%. Therefore, neural network are suitable for classification of failure mode in check valve and these results are agree well with the actual failure modes.

Table 1 Neural network results obtained from 'disc wear, and 'foreign object' failure modes.

Disc Wear Size	Pressure	Output (mm)	Error (%)	Foreign Object Size	Pressure	Output (mm)	Error (%)	Foreign Object Size	Pressure	Output (mm)	Error (%)
1.0mm	3bar	0.9789	2.11	0.5mm	3bar	0.4944	1.12	1.5mm	3bar	1.905	27
	6bar	1.0397	3.97		6bar	0.5327	6.54		6bar	1.485	0.99
	9bar	0.74	26		9bar	0.4863	2.75		9bar	1.534	2.25
2.0mm	3bar	2.0472	2.36	1.0mm	3bar	1.0095	0.95	2.0mm	3bar	2.476	23.8
	6bar	1.9762	1.19		6bar	1.273	27.3		6bar	2.051	2.53
	9bar	1.9766	1.17		9bar	1.0929	9.29		9bar	2.292	14.6
3.0mm	3bar	2.9403	1.99	1.2mm	3bar	1.3159	9.66	2.4mm	3bar	2.662	10.9
	6bar	2.9364	2.18		6bar	1.1700	2.53		6bar	2.451	2.14
	9bar	3.0609	2.03		9bar	1.2412	3.43		9bar	2.292	4.48

3. Conclusion

The current neural network gave results for the 4-inch valve that were consistent, as far as relative AE r.m.s, amplitude, signal strength and frequency are concerned. The results using the neural networks agree qualitatively with the results obtained using back propagation neural networks. In addition, it was shown that leak size can be determined with neural network. It is difficult to distinguish failure mode of check valve, nevertheless it was possible to train a neural network so it can be distinguish 'disc wear' and 'foreign object' failure mode including its leak size with sufficient accuracy.

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