Condition Monitoring through Advanced Sensor and Computational Technology

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1. Introduction

In order to successfully implement the extended-life operation plan of the nuclear power plant (NPP), predictive maintenance based on on-line monitoring of deteriorated components becomes highly important. In this work, we present progresses in the development of an advanced monitoring system to detect the health condition on check valve failures and pipe wall-thinning phenomena. 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. Pipe wall-thinning is usually caused by Flow-Accelerated Corrosion (FAC) under the undesirable combination of water chemistry, flow velocity and material composition. A piping elbow in the moisture separator/reheater drain line on the secondary waterside of a PWR is chosen as a monitoring target.

2. Methods

2.1 Check Valve Failure

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 artificially worn disks (0, 25, 50 and 70%)
Valve with artificially leakages (0, 25, 50 and 70%)
Loop condition (steady, transient 0, 3, 6 and 9bar)

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. AE has been used to monitor disc position and movement of a disc, mechanical condition of the valve and back leakage when the valve is closed. Ultrasonic technique was used to detect a missing or stuck disc. Accelerometers have been used to detect mechanical vibration signals which respond to pressure waves over a low-frequency rang.

These tests were carried out using water as the process fluid. Check valves were initially tested in a "good" condition, and then with one or more simulated degradations and operational failures. Several flow conditions were also used.

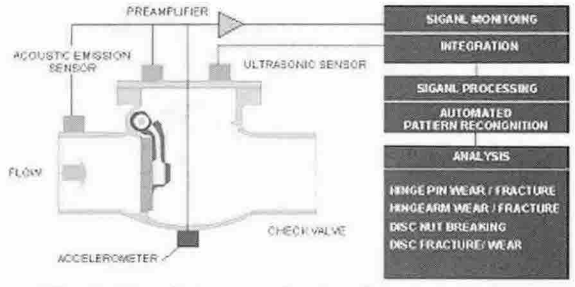


Fig. 1. Condition monitoring for check valve.

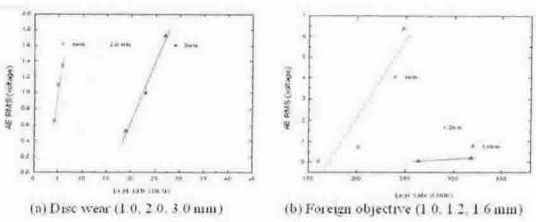
2.2 FAC Failure

We developed a combination of sensors, ranging from chemical electrodes to mechanical vibration sensors to monitor the thickness change of the elbow, which can be still economical option. Electrochemical Corrosion Potential (ECP) and pH are chosen as electrochemical parameters, and vibration mode change, displacement, etc. are chosen as mechanical parameters to monitor the wall thinning phenomena. To support FAC monitoring, we develop reference and pH sensors applicable to high temperature environment. Ag/AgCl electrode is developed to measure ECP and the gold plated Ni-electrode is for pH. By combining two parameters, we can predict whether the environment is corrosive or not. Vibration is considered as a promising candidate as a mechanical parameter. Various sensors are surveyed and some are chosen based on FEM analysis result, which shows the approximate vibration range according to the thickness change.

3. Results

3.1 Check Valve Failure

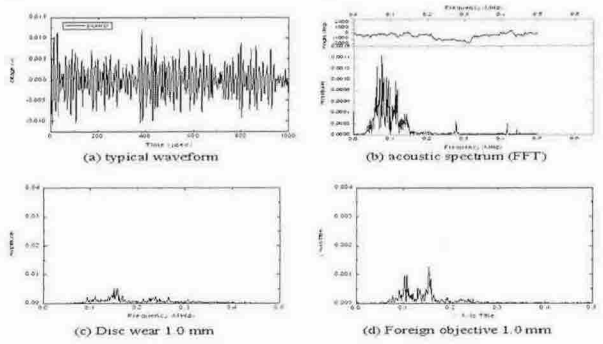
Figure 2 presents the data between acoustic r.m.s data and flow rate obtained from disc wear and foreign objective. Flow rates through the leak were measured by means of ultrasonic flow meter. As shown in Figs. 2(a) and 2(b), a linear relationship is observed. The analyses of the results suggest that acoustic signals depend on leak rate.



(a) Disc wear (1.0, 2.0, 3.0 mm) (b) Foreign objective (1.0, 1.2, 1.6 mm)

Fig. 2. The AE r.m.s value vs. leak rate.

Figure 3 shows the typical AE waveform and its spectra that obtained from resonance (R15) AE sensors in disc wear and foreign objective. A primary peak with high amplitude is observed at about 90-100 kHz, and readily identified in the frequency range from 300 and 450 kHz. These signals will not provide serious effects on the detection of leaks. The waveforms reveal the continuous random fluctuations, which are the characteristics of leak induced AE. The plots were generated from 1024 data samples of waveforms.



(a) typical waveform (b) acoustic spectrum (FFT)

(c) Disc wear 1.0 mm (d) Foreign objective 1.0 mm

Fig. 3. Spectrums between disc wear and foreign objective

3.2 FAC Failure

To test mechanical sensors, elbows with different thickness are used to identify resolution with thickness change. To test electrodes, we simulate water chemistry with different pH and ECP combinations, which is prone to accelerate the FAC. To simulate the effect of ECP, both reducing and oxidizing environmental condition is planned by adding hydrogen and oxygen. Amount of thinning at given pH is predicted using FAC model as a function of time.

An accelerometer, optical fiber displacement sensor and a capacitance displacement sensor were used for evaluation on the characteristics of mechanical vibration by thinning of FAC. Figure 4 illustrates the results of the frequency response of low and high frequency at the steady condition of pull-down test. There were dominant peaks in the vicinity of 8 Hz and 22 Hz in the case of pump off and a charging pump on. Figure 5 shows the results of the frequency response of the simulated FAC by grinding the outside elbow pipe. We can observe a little frequency shift about 20 frequencies by artificial thinning.

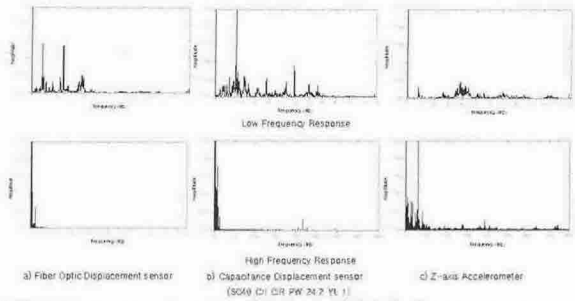


Fig. 4 Frequency response of low and high frequency

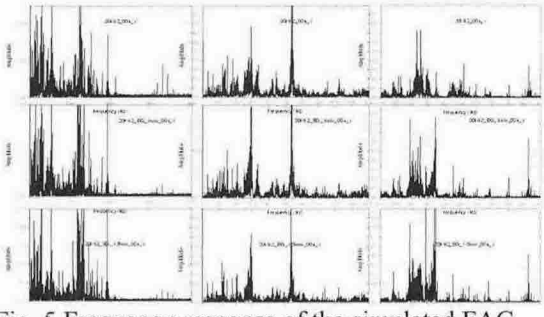


Fig. 5 Frequency response of the simulated FAC

4. Conclusion

The primary objective of this research is to investigate the advanced condition monitoring systems on detection of check valve degradation and FAC phenomena. There is certain benefit that we can optimize the advanced sensors for the advanced condition monitoring systems.

Acknowledgement

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REFERENCES

[1] V. Luk, J. T. Kim, I. S. Hwang, et al., Condition Monitoring Through Advanced Sensor and Computational Technology, Proposal for the International Nuclear Energy Research Initiative, Contract Number DE-AC04-94AL85000, 2001.