Simulation of Vibration Characteristics on the Artificially Corroded Elbow With Spectral Estimations

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1. Introduction

A Nuclear Power Plant has very sophisticated piping systems operating in a very aggressive erosion and corrosion environment with turbulent flow, high temperature and pressure. These adverse operating environments make a piping system very vulnerable to accelerated wear and degradation. [1, 2] But there is no practical way to monitor the wear and degradation during operation. In this study, we suggested and investigated the monitoring methodology for the wear and degradation of the piping system by using the accelerometer. The suggested methodology was based on the changes of the vibration mode due to the corrosion on the pipe. [3] The accelerometer could be used to monitor the vibration of the system. For confirming the change of the characteristics of the vibration signals due to the corrosion, we simulated the vibration mode of piping system with artificially corroded elbow. For simulating the corroded piping system, we made three artificially corroded elbows. For analyzing the characteristics of the vibration signals, we used the power spectrum density with auto-regressive model. From simulation and analysis, we had a signature for wear and degradation on the piping system.

2. Experiment Conditions

We developed a test loop to collect the vibration data of a piping system. Since the real corrosion experiment is a very tedious and dangerous test, we investigated the change of the characteristics of the vibration signals due to the corrosion on the elbow through the simulated experiment. Figure 1 shows the test loop and its operating pressure is about 20 bars and the flow velocity is from 1m/sec to 3m/sec. The elbow in piping was chosen as test specimens to maximize the effect of corrosion, that is, vibration. A 3-axis accelerometer was used to detect the vibration on the pipe and its sampling rate was 20 KHz. For simulating the corroded piping system, we made three artificially corroded elbows with thickness of 2.6mm, 1.6mm and 0.6mm as shown in Fig 2. The artificially corroded elbow was made from grinding inner region of elbow like the chemically corroded elbow.

3. Auto-Regressive Model for Estimating Power Spectrum Density of Vibration Signal

The frequency spectrums of the vibration signals with the FFT analysis are unclear and those are hard to understand the system characteristics such as the peak frequencies and amplitudes. In an attempt to alleviate the inherent limitations of the FFT such as an ambiguity and the side effects, a spectral estimation procedure has been introduced in this study. The auto-regressive model was introduced as the estimation procedures. [4] Major motivation for the selection of the AR model is the higher frequency resolution achievable, and if any, it can be determined by the ability to fit an assumed model with a few parameters to the measured data. For representing the characteristics of frequency of the vibration signals, we used 12th-order AR model. In the AR model, the determination of order p is important problem to acquire adequate frequency resolution. Generally speaking, the order p can be intuitively determined the concerning the number of peak frequencies. We chose the order p as 12 enough to represent 3 or 4 peak frequencies.

4. Results of Vibration Data Analysis

The results in the Fig. 3 showed the typical y-axis power spectrum densities of the vibration signals on the artificially corroded elbows and the not corroded elbow. The thickness of the not corroded elbow was 3.6mm. The operating condition of the data was pressure of about 20 bar and temperature of about 40℃ and the flow velocity was within 1m/sec to 3m/sec in our experiment. In the figure, the x-axis means the normalized frequencies (x̣ rad/sample) and its range of absolute frequency covers from 0 kHz to 10 kHz. The y-axis means power spectral density (dB/rad/sample).

The differences of characteristics were shown arrow mark in the figure. We found that there were small changes in the frequency location and amplitude when the thickness of elbows was changed. In addition, we found that the peak frequencies were independent of the operating conditions such as pressure, temperature and flow velocity, but the amplitudes of power spectrum densities were dependent on the operating conditions.

5. Conclusions

From simulation of vibration characteristics, we found that the frequency characteristics of the vibration signals due to the elbow thickness were changed. Though the changes of the peak frequencies were small, this showed that monitoring the vibration characteristics would be a methodology to detect the corrosion on the elbow. After real chemical testing for a flow-accelerating-corrosion, we will verify our methodology and will develop an on-line condition monitoring system through monitoring the vibration of a piping system.

Acknowledgements

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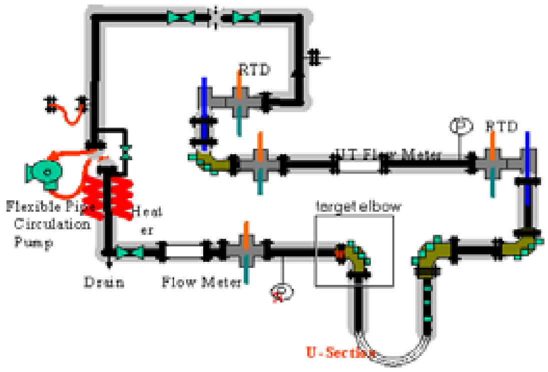


Fig.1 Test Loop for FAC Simulation

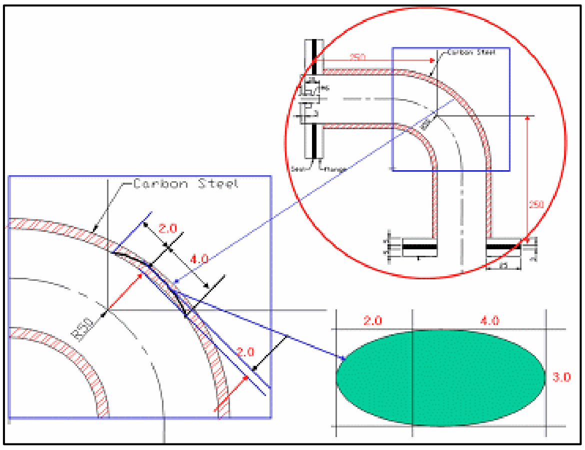
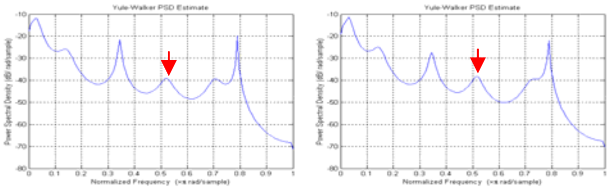
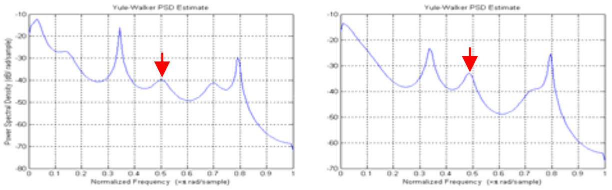


Fig.2 Shapes of Artificially Corroded Elbows



(a) 3.6mm elbow



(b) 2.6mm elbow

(c) 1.6mm elbow (d) 0.6mm elbow

Fig.3 Power Spectral Densities of Vibration (y-axis)