2005년도 대한전기학회 하계학술대회 논문집 2005. 7. 18 - 20

시간-주파수 분석을 이용한 파이프 부식감시

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Application of Time Frequency Analysis to On Line Monitoring of Pipe Corrosion

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Abstract - Time-frequency analysis (TFA) method was applied to identify the integrity of the internal local surface of a pipe where some chemical corrosions are likely to occur by acid mixed in the coolant of nuclear power plants. The spalling out of internal material pieces by corrosion induces some transient signals and the change of structural vibration of a local point in the pipe. It is therefore possible to detect the corrosion detachment through the measurement of the transient acoustic signals or the vibration signals. In this presentation, the TFA was configured on the vibrational signal data of the pipe and it is identified that the TFA can provide an important information, i.e., the amplitude fluctuations in the instantaneous frequency of each characteristic frequency.

1. 서 론 (Introduction)

Pressure vessels and heat exchangers such as steam generators in the Nuclear Power Plant (NPP) have 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. But there is no practical way to monitor the wear and degradation during an operation.

In this study we analyzed the vibration signal measured by an accelerometer to monitor them on the pipes. The accelerometer is convenient to install and strong against harsh environments. For the analysis, the cone-shaped kernel the time frequency distribution (CKD) is used. It is one of time-frequency analysis (TFA) methods being used in the analysis of a noise and an acoustic signal over the past few years.[1][2] From CKD's, we can obtain a better signature for a wear and degradation on a pipe than that by the frequency analyses.

2. 본 론

2.1 신호 취득 (Data Acquisition)

Moisture separator and re-heater (MSR) drains in a NPP secondary side were selected for the flow accelerated corrosion (FAC) monitoring, since MSR drains with a single-phase flow have a high susceptibility to FAC. As shown in Fig. 1, we developed a test loop to collect the vibration data for a FAC. Its operating temperature (150°C) and pressure (20 bar) are similar tothe plant condition.[3]

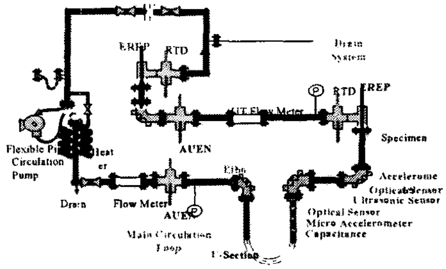
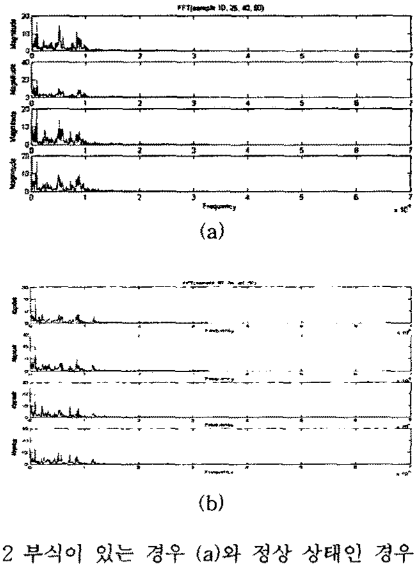


그림 1 FAC용 모사 실험 장치
Fig.1 Test Loop for FAC Simulation



(a)

(b)

그림 2 부식이 있는 경우 (a)와 정상 상태인 경우 (b)에 대한 주파수 스펙트럼
Fig. 2 Spectra for corrosion (a) and normal (b)

The elbow pipe and U-shaped pipe are chosen as test specimens to maximize the effect of a FAC, that is, a vibration. A 3-axis accelerometer is used to detect the vibration on the pipe and its sampling rate is 20 KHz.

The acquisition data was analyzed by a Fourier transform, MUSIC and an auto regressive method.

The results in Fig. 2 showed that there were small changes in the frequency location and amplitude when the pipe thickness is changed, but they were not enough to identify the degree of wear and degradation on the pipe. So another analysis method is required.

2.2 시간-주파수 분석 (CKD)

The TFA is effective for the analysis of time-varying and transient signals, which represent the intensity of an energy for a signal in the time-frequency domain. The general class of the time frequency distributions (TFD) for an analysis was introduced by Cohen [4] and this is expressed as

$$C_f(t,\omega,\phi)=\frac{1}{2\pi}\iiint e^{j(\xi\mu-\tau\omega-\xi t)}\phi(\xi,\tau)f(\mu+\frac{\tau}{2})f^*(\mu-\frac{\tau}{2})d\mu d\tau d\xi. \quad (1)$$

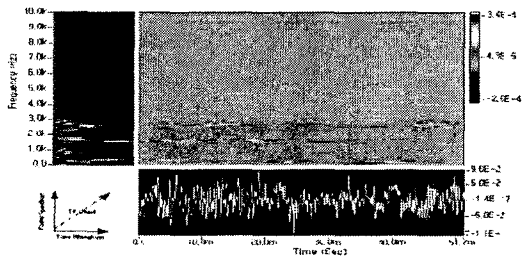
In Eq.(1), $f(\mu)$ is a time analytic signal and $f^*(\mu)$ is its complex conjugate. ϕ is is a kernel function which determines the size and shape of the cross-term obscuring the true energy distribution over the time and the frequency. How to reduce the cross-term optimally is a key point in the TFA. CKD is one of TFA methods developed to reduce the cross-terms. In CKD, the choice of a scaling factor should be optimized for an application, which is signal dependent. In addition, an exponential distribution (ED) is used to verify the CKD. The kernel functions for the CKD and ED are respectively

$$\phi(\xi,\tau)=g(\tau)|\tau|\frac{\sin(a\xi\tau)}{a\xi\tau} \quad (2)$$

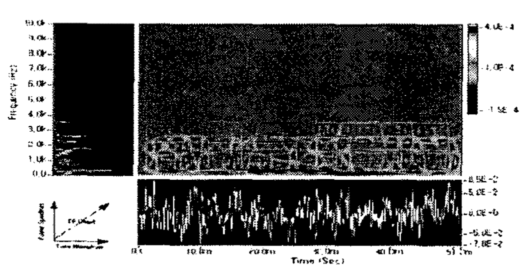
$$\phi(\xi,\tau)=e^{-\xi^2\tau^2/\sigma} \quad (3)$$

2.3 진동신호 분석결과 (Analysis Results of Vibration Data)

CKD's in Fig. 3 are represented with a software provided by National Instruments Corp.



(a)



(b)

그림 3. 부식 발생(a) 및 정상 상태(b)에서 CKD 결과
Fig. 3 CKD's for corrosion (a) and normal (b)

We calculated them by changing the scale factor until we obtained the optimal distribution for an evaluation. DC bias from the acquisition data is eliminated by an averaging method to reduce the interference on the CKD's. The data for the analysis is arbitrary sampled and the length of each sample is 1,024 data per sample. And the ED in Fig. 4 provides a 3-dimensional distribution, in which the x-axis is the time, the y-axis the frequency and the z-axis the amplitude.

From the CKD's we identified the small frequency shift and some amplitude changes in the characteristic frequencies (500, 1,600, 2,700 Hz) which have the signature of a vibration. This is the same as the result of the frequency analyses. But the CKD provides one more piece of information - the amplitude fluctuations in the instantaneous frequency of each characteristic frequency.

In CKD's for a corrosion, we can see peaks with some period. These peaks are expected to occur with a shorter period when a corrosion proceeds. In addition, the ED verifies the peaks and their fluctuations easily in each characteristic frequency.

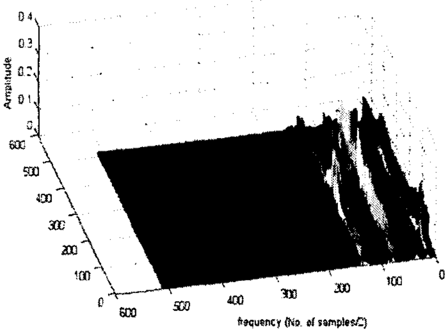


그림 4. 부식이 있는 경우의 ED 결과
Fig. 4 ED for corrosion

3. 결　론 (Conclusion)

The development of an on-line condition monitoring system through pertinent sensors is highly desirable to evaluate the severity of the FAC phenomenon in piping components and to take action before an excessive degradation. The result by the CKD can provide more information for an evaluation of the integrity of a piping component, moreover under the condition that a misunderstanding may lead to a loss of its economy.

[감사의 글]

본 연구는 과학기술부의 원자력 연구개발 프로그램의 지원 하에 수행되었습니다.

[참 고 문 헌]

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