FREQUENCY SHIFTING SIGNAL DETECTION AND ANALYSIS OF BOILER TUBE LEAKS

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1 Introduction

The availability of utility power plants has become of major importance over the last 20 years. Substantial efforts have been done to reduce forced outage. Variety methods have been concentrated on to improve techniques for the inspection and evaluation of critical plant components prior to failure.

An important part of this monitoring ability deals with early detection of leaks in boiler tubes. In utility boilers, early detection of leaks is primarily a financial issue. High pressure steam escaping from a tube leak can cause extensive damage to the adjacent tubes, which increases repair costs and outage length(hours). Especially forced outage occurred during peak demand may cause a lot of problems on national energy supply strategies. When a leak occurs in the furnace, reliable leak detection capability also becomes a safety issue. Moreover property damage and personal injury are the primary concerns.

Air-borne acoustic sensors were first developed during the early 1970s in Europe and later applied in power generation boilers. Structure-borne technology was introduced into the power plants market in the late 1990s. Today most utilities are considering on changing air-borne type sensors to structure-borne type sensors and it's technique.

However there exists limitations on early leak detection in both technique.

2 Background and Leak Detection System

2.1 Boiler Tube Failure Experience

In Korea there have been over 30 incidents of tube failures which caused plant shut-down. According to Fig. 1 the most frequent part was super-heater. In case of other counties, there are a variety of root causes of boiler tube failure likewise in NSW(New South Wales in Australia). Since 1998 thermal fatigue, grit erosion, and welding defects have caused most failures. Looking at the total number of failures since 1987, material defects and corrosion fatigue caused many leaks but have now fallen to insignificant number(Fig. 2)[1]. In case of Youngheong power plants(Fig. 1), we constructed new plants over 800MW so they need stabilizing time. The tube materials were not enough to meet boiler operation conditions. Significant efforts and burden have been pouring into improving actions to prevent tube failures. Moreover if we think boiler tube failure is inevitable, the next option we can take is to develop early and precise detection method that leads to early warning.

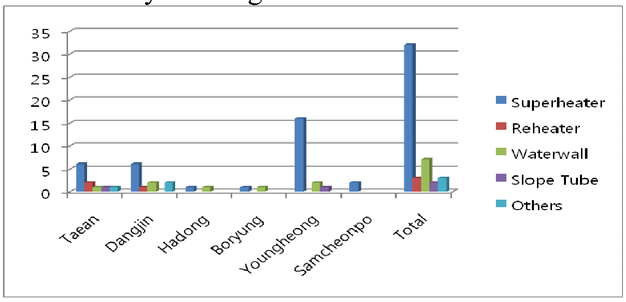

Fig. 1 Tube leak experience in Korea 2005~2009

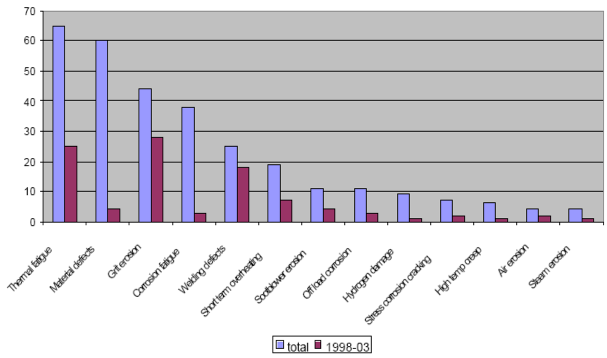

Fig. 2 Types of root cause in boiler tube failure

2.2 Boiler Tube Leak Detection System

As a leak develops in a boiler tube, turbulence by escaping fluid generates pressure waves within the contained fluid itself, throughout the flue gas into which the fluid is escaping, and within the container structure. These are commonly referred to as airborne, and structure-borne acoustic waves, respectively.[2]

To detect leaks, the energy associated with these mechanical waves are converted into electrical signals with a variety of dynamic pressure transducers (sensors) that are in contact with the medium of interest. Several methods of signal processing are available that allow the voltages generated by these sensors to be evaluated for the presence of a leak. As mentioned above, leaks in a boiler tube generate sound waves in three media. The decision regarding which types of acoustic waves are most reliably detected is important from both functional and economical considerations. This decision, in some cases, is not simple. Factors such as background noise level, sound attenuation within the medium, signal processing strategy, and installation costs play a role.

Since 1974, power plants have used airborne leak detection predominantly in large commercial boilers. Airborne methods are well established and have detected leaks as much as a week before any other means available.

In airborne applications, microphones or low frequency resonant piezoelectric transducers are coupled by hollow waveguides to the gaseous furnace medium. Most leak detection system usually attach waveguides through penetrations in inspection doors, unused soot-blower ports or the casing.

The structure-borne method of leak detection has found applications in valves and pressurized pipelines. Under a recent Electric Power Research Institute (EPRI) sponsored project, a high frequency structure-borne approach was found to be the best method for detecting leaks in feed-water heaters.

In Korea we are applying the structure-borne technique using piezoelectric transducers coupled to acoustic emission type waveguides. We welded them on the boiler tube membrane as shown in Fig. 3 and Fig. 4.

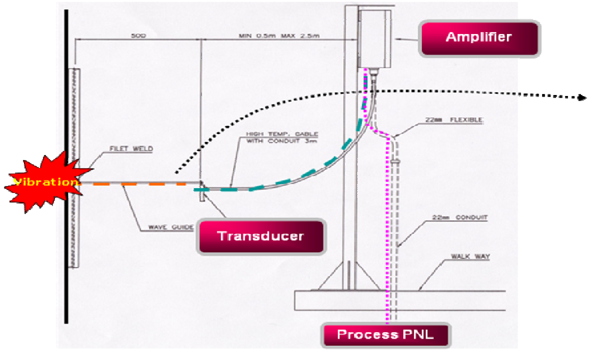

Fig. 3 Typycal Diagrame of structure-borne type

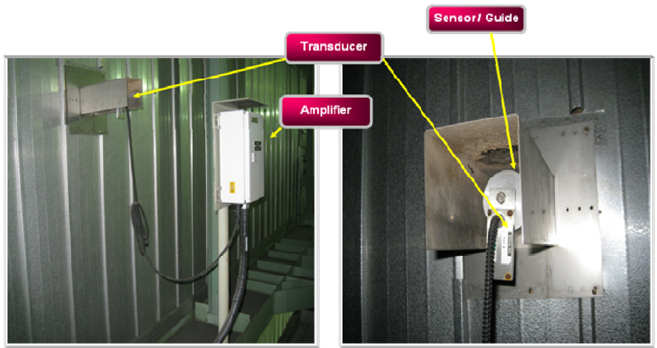

Fig. 4 Attachment of AE sensors at outside boiler

3 Review of boiler tube leak detection system

3.1 Boiler tube leak detection system in power plants

All utilities in KEPCO(Korea Electric Power Corporation) except HRSG(Heat Recovery Steam Generator) are monitoring boiler tube leaks to prevent further damage a certain extent. Every tube leak detection system has sensors located on the water wall which can sense leakage noise(Fig. 5). When tube leaks happen, the system displays RMS trends and alarms. To confirm leaks plant operators should review boiler operation parameters such as furnace pressure variation, make up flow change, difference between feed water flow and main steam flow etc.

However in case of a tiny pinhole leak, to decide whether it’s a leaks or not is not easy as some operation parameters especially furnace pressure and make up flow don’t vary significantly. But only leak sound RMS decibel always shows higher than normal condition(Fig. 6).

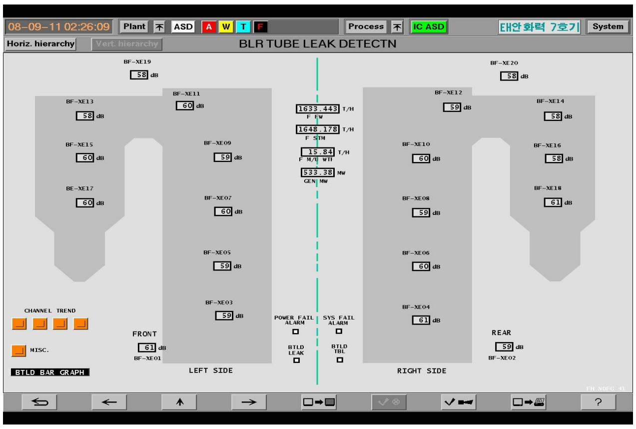

Fig. 5 Leak detection system layout

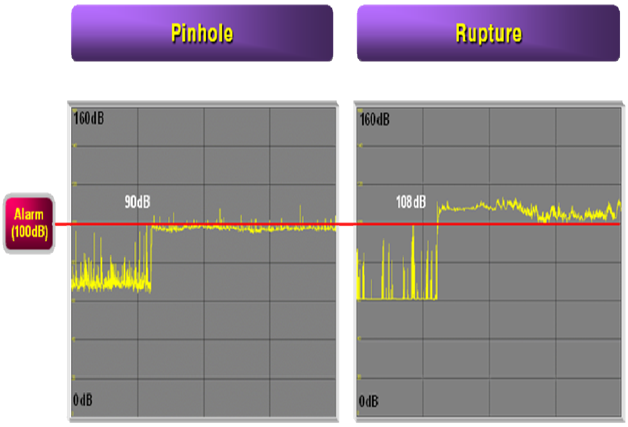

Fig. 6 RMS trend of pin hole and rupture

3.2 Limits of boiler tube leak detection system

All of detection systems can show alarm according to the certain logic. However when a tiny pinhole happens, to make decision for leakage needs more time. EPRI research results showed that the relationship between secondary damage, outage length, and cost(Fig. 7). As the number of tubes suffering secondary damage increases above four or five tubes the average outage length and cost increase[3]. So early detection before secondary damage can suggest repair extent and maintenance parts with proper preparation. Unfortunately most of boiler tube leak detection systems don't apply frequency spectrum function. So that without confirming leak position by naked eye, we must spend additional time to do hydraulic static test for pointing out. It means that we have to study other method to verify leaks. So frequency analysis for leaks compare to normal condition is the one to consider.

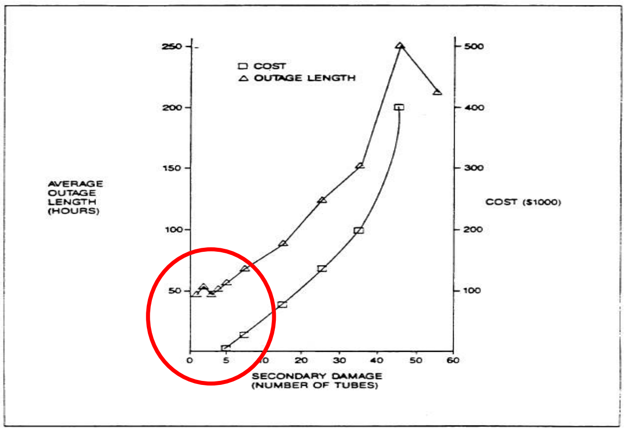

Fig. 7 Relations of outage length, cost and secondary damage

4. Study of tube leak frequency

4.1 Normal operation frequency

In leak detection applications, the most crucial factor to consider is background noise within the propagation medium of interest. Almost all background noise can be characterized as white noise combined with discrete frequency noise.

White noise can be defined as containing components at all frequencies within a range or band of interest. We consider both normal boiler noise and leak noise are white noise. Normal noise shows low frequency white noise (rumbling) while leaks display higher frequency white noise (hissing).

At Taean #7 boiler test we could get that normal operation frequency band was under or around 30kHz.(Fig. 8)

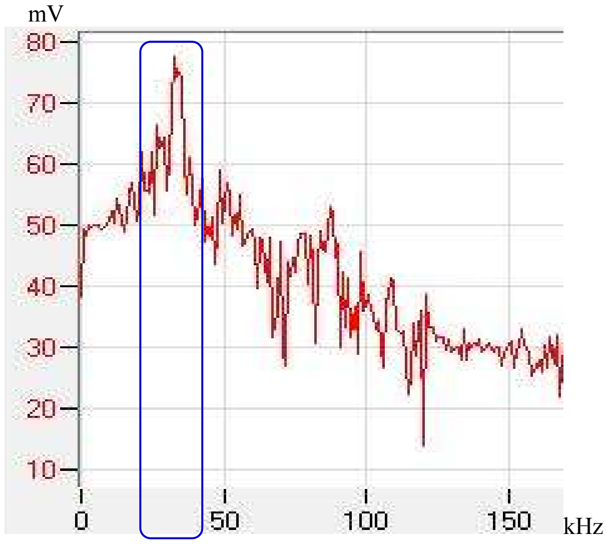

Fig. 8 Frequency spectrum for normal operation

4.2 Shifting of leak frequency

In the experiment to simulate acoustic emission signals during leak, we applied and analysed a rectangular slit (0.2mm*15.7mm) on pressure chamber(Fig. 9)(Fig. 10). The gas pressure was 100 bar nitrogen from a gas tank. The experiment used a wide band type transducer to receive leak gas signals. The leak signals were transformed to digital signals through μ-DiSP(PAC ltd.). The AEWin(PAC ltd.) analysed Vrms and frequency spectrum. The result showed leakage frequency shifted above 50kHz(Fig. 11). It means that we have to monitor typical frequency bands to confirm leak condition.

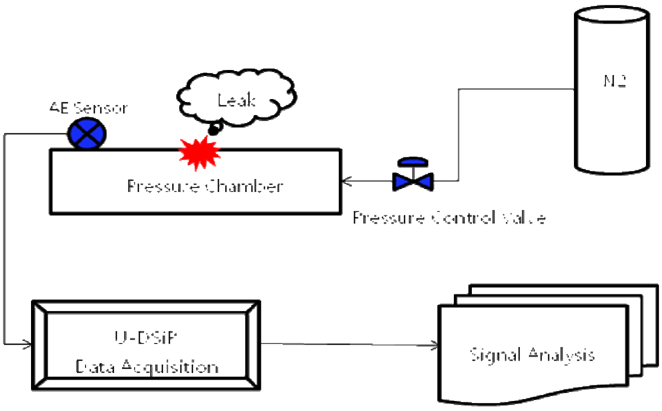

Fig. 9 Typical diagram of experiment

Fig. 10 Leakage simulation slit

4.3 Field test of leak frequency

We could confirm that leak made different frequency bands above 50kHz compare to normal condition (Fig. 12). In the event the Samchonpo #3 boiler tube leak alarm, we applied acoustic sensors at the site and revealed leaks happened. Eventually some rips existed at undulated plate using for air supplying to burners. After removing insulation, we figured out air-in-leak caused by negative presure in boiler(Fig. 13).

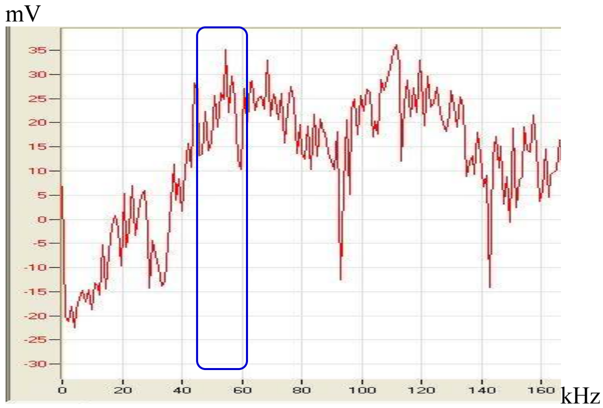

Fig. 11 Leak frequency from slit at pressure chamber

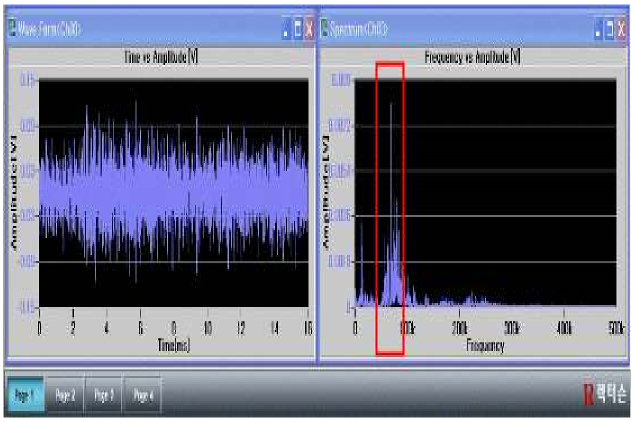

Fig. 12 Leak signal detection above 50kHz during boiler operation

Fig. 13 Damage of undulated plate

4 Conclusions

Frequency shifting has happened above 50kHz in pressure leak. Therefore, monitoring frequency band above 50kHz is essential to decide leaks.

Applying frequency analysis function in tube leak detection system is important.

Providing frequency figure in monitoring system can improve detection ability than monitoring noise intensity(dB). With checking out frequency shifting bands and RMS signals, we can confirm tube leaks.

References

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