Development of Precise Source Location and Leak Monitoring Technique 3D Point Location Method for Power Plant Boiler Structure

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Abstract. This paper describe novel leakage detection system using three-dimensional (3D) source location technique enabling to detect a leak happened on a main boiler tube (Super Heater, Reheater, Economizer, Waterwall) of 500MW class thermal power plant. Acoustic Emission Testing method, one of the Non-Destructive Testing method was applied to detect the low-and high-frequency leakage signal for boiler structure. To do this, this study apply complex sensor for vibration and acoustic emission during normal working period.

In boiler tube leak detection, 3D point location technique is applied and verified by detecting of actual tube leak in large scaled structure. Our results show that we can detect and prevent unexpected plant accident early, and contributes to maximize the effectiveness of power generation.

Introduction

Boiler tube of thermal power plant consists of SuperHeater, Reheater, Economizer made of vertical and horizontal structure in furnace and Waterwall of the outer -wall and this is one of the important facilities to maximize efficiency. The loss due to one day stop of power generation caused by the problem in boiler tube which is an important facility is over 6 hundred thousand USD per day, 4 million USD per week and it costs from tens of millions of dollars to nearly hundred of million dollars on an yearly basis and it is critical to detect and establish countermeasure about this.

Major causes of Boiler Tube Failure are four kinds which are Creep, Fatigue, Corrosion, Erosion and among them, Corrosion Fatigue and Underdeposition Fatigue takes approximately 52% [1], when these kinds of boiler tube problems happen, it is very important to maximize power generation efficiency by minimizing downtime through rapid detection and replacement with the facility determining the problem based on the temperature, pressure, flow, etc. installed around the place depending on follow-up control.

For the improvement of performance and reliability and maintaining safety of the power equipment, there is growing interest in the technology to monitor real-time status of the boiler and predict life expectancy of the equipment as well as the technology to detect the problem in early stage.

Jirapong Lim [2] put emphasis on experimental study of small leak using crest factor and count rate for normal and abnormal condition, Lu Xueqin [3] made study on corrosion and erosion through Scanning System which is NDT method of the Water wall tube Inspection, Peng, Liansuo [4-6] made study on leaking source by utilizing a variety of algorithms for leakage signal based on mathematical calculation, Gao [7] made study on the four major tube leakages through temperature, pressure and flow.

Those studies are the experimental studies applying mathematical algorithms for limited tube rather than four major tubes and it was a study primarily to evaluate the leak evaluation, and this cannot present accuracy for the integrated leakage evaluation and leak location based on actual data for the whole boiler system.

Whereas, in case of commercially available conventional Boiler Tube Leakage Detection(BTLD) system[8,9] makes alarm when a signal higher than normal value is input in the microphone located nearest to the leaking place or acoustic sensor utilizing accelerometer and this makes the staff in charge take considerable time to verify whether or not of the leakage and check the location of the leakage after the stop of power generation and this causes enormous loss due to the stop of power generation.

This study proposed boiler tube leak monitoring technology utilizing Acoustic Emission Testing(AET) method which provides information to make it possible for manager to execute facility maintenance work efficiently by figuring out any leak occurred in the entire boiler tube precisely and providing the information of the location with three-dimensional location Coordinates and the validity of it was confirmed by applying this to 500MW class thermal power plants.

2. The Principle and Overview of Leak

In large structures such as power plants in order to perform the leak detection, structural features of the target and identify the signal transfer path, and then consideration for leak signal features and detection method is required.

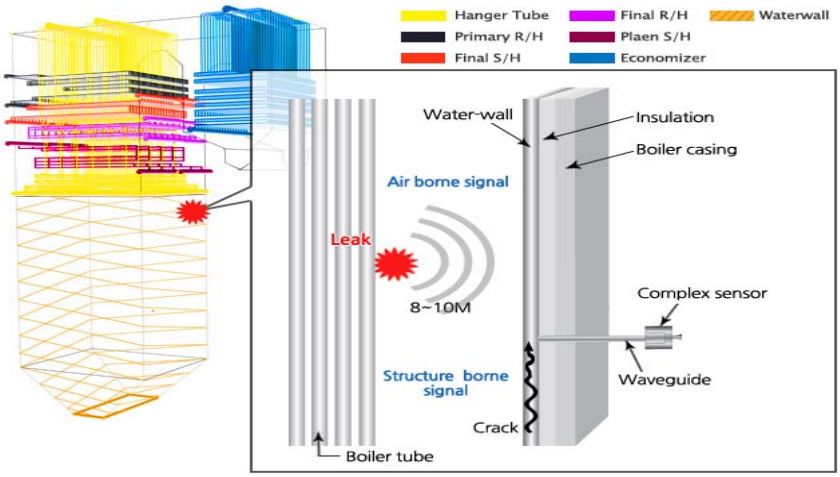

Fig. 1. Tube Leak Detection Method

Figure 1. shows the leak detection methods for structure of the boiler tube. If there is leakage in superheater, reheater and economizer which are the main tubes located inside the boiler, the signal will be vibrating and pass through a layer of air and reach the boiler water-

wall. Boiler external walls (water-wall) leakage signal will be passed through the structure which is waveguide (acoustic waveguide) installed by welding on membrane tubes of external wall.

Leak caused by high pressure inside the pipe wall has the frequency range of broadband pipe and makes inside of the pipe vibrate.

Only low-frequency signal can be passed onto fairly long distances through the gas layer inside of the pipeline. Leak signal has unique acoustic characteristics.

If a leak occurs, supersonic speed acoustic energy is generated from the gas erupted. This acoustic emission has the element of continuous broadband frequency (1 kHz-1MHz) and element of narrow band intermediate high-frequency (175 kHz-750 kHz) for most of the cases.[10]

In order to apply leak monitoring system for large power plant separated by field, equipment rooms, main control room is installed, as shown in Figure 2 consists.

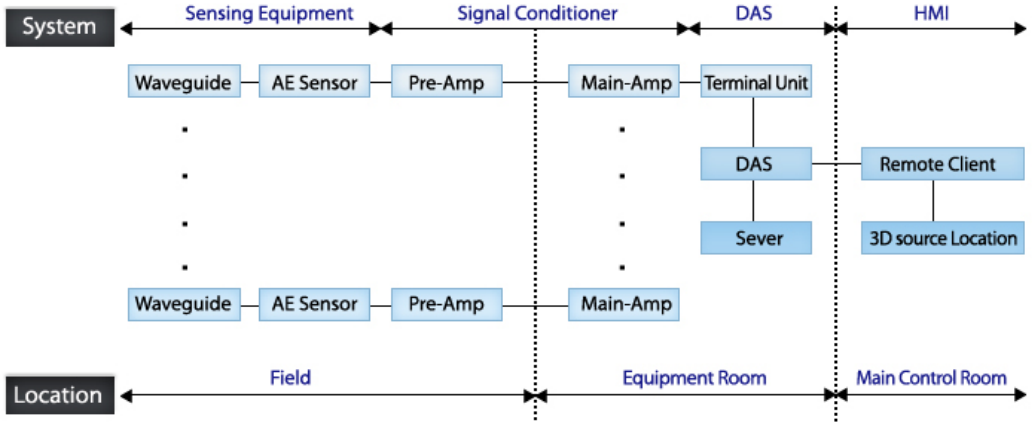

Fig. 2. System configuration of BTLD

In technical point of view, there is a need for convergence and complex technology integrating, the sensing technology collecting various signal occurring inside and outside of the boiler through complex sensor for vibration and Acoustic Emission installed on the exterritorial side of the boiler, hardware design and manufacturing technology including the technology to amplify and filter the collected signal, IT-based signal processing technology which can isolate leak signal from signal source of the acoustic emission and in the background noise environment caused by temperature, pressure and combustion at electricity generation, the knowledge-based predictive and diagnostic technology which can perform predictive maintenance by classifying the failures by each pattern based on finally collected data and the 3D analysis technology providing leakage location three dimensionally.

3. Leakage Source Location Estimation

Estimating the position of leakage using sensor RMS ratio

The position of a leakage source in a two dimensional plane can be estimated by using more than three sensors and their RMS magnitude ratio (RMS3 > RMS2 > RMS1) as show in Fig. 3.

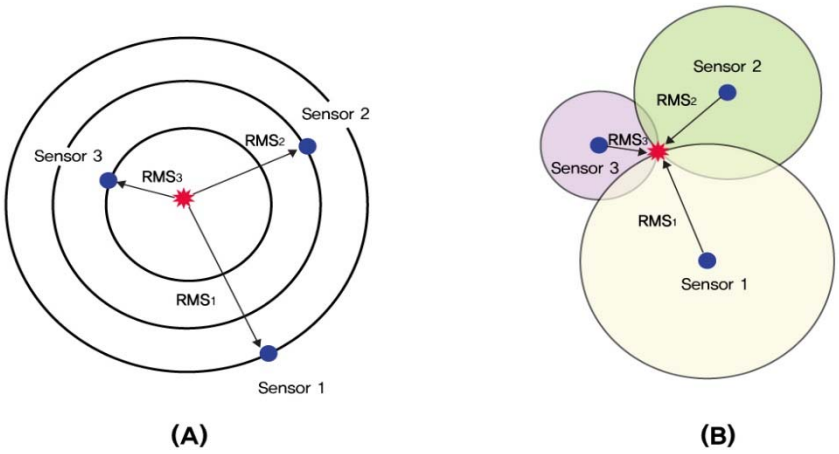

Fig. 3. Estimating the position of leakage in 2D by means of sensor RMS magnitude ratio [20]: (a) Signal propagation from actural leakage point to sensors; and (b) Estimated leakage propagation by using sensons.

4. Experiment of Tube Leak

Installation of BTLD

In order to apply BTLD to a coal-fuel power plant, a 3D model like Figure 4 was made using a left hand coordinate system after reviewing the drawings of the boilers and visiting the field. The leakage detection of the 500 MW power plant is generally carried out using 16 ~ 28 sensors. In this study 28 combined acoustic emission and vibration sensors were used.

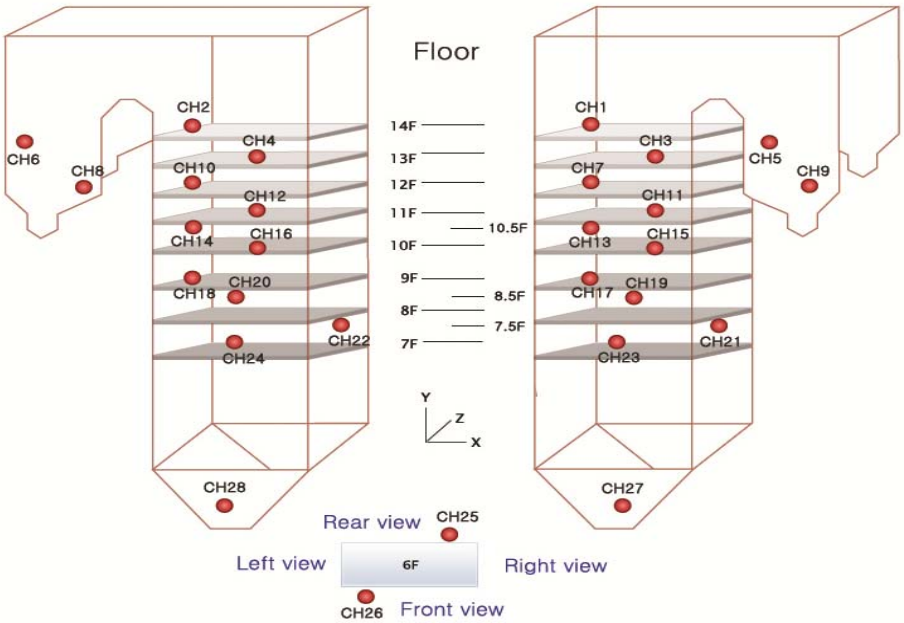

Fig. 4. Mirror type sensor location map for sensors (28 channels): (a) left view; and (b) right view.

The specifications of BTLD hardware components are shown in Table 1.

Table 1. BTLD components specifications

Title	Specification		
	Description	**Specification**	**Maker**
Sensor	Vibration/Acoustic Emission	20mV/g, ~20kHz, 63dB, 50~200kHz	Fuji Ceramic
Pre amplifier	1st amp w/ filter	20/40 dB, 2~20kHz & 50~200kHz	RECTUSON
Main amplifier	2nd amp w/ filter, RMS/RAW output	0/20/40 dB, 2~20 kHz & 50~200kHz	
DAS	High Speed Data Acquisition System	3M SPS/CH , 14bit	
Software	3D Source Location Software	RMS Trend, 3D Tube modeling, 3D Source location	

The BTLD components are separately installed at field, equipment room and main control room of the plant.

Detection and trend of BTLD's leakage signal

Figure 5. shows the trend of the top 4 channels having considerable changes among the signals of 10 sensors as described above. If leakage occurs, the sensor closest to the leakage will respond most sensitively and show a considerable change. It is expected that the leakage source will be around these sensors. It was found that the noise level of the sensors located near the leakage source gradually increased by about 5~8 dB more than the normal background noise level. It is estimated that this is the cause of the leakage. In addition, the trend of these signal changes linearly increases until the tube is ruptured as time goes by. It is possible to estimate the existence of the leakage based on these signals.

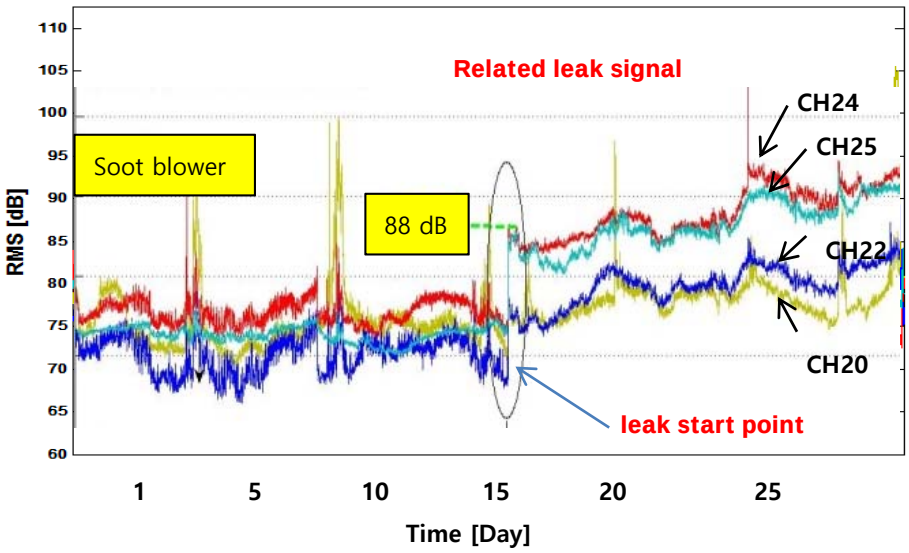

Fig. 5. top 4 channels's RMS Trend

In this study, more accurate point location technology in which the ratio of signal size is added to the zone location is applied to the coal-fuel power plant and the area which has a high density of cluster is considered to be near the actual leakage point. Furthermore, it was

confirmed by using the 3D position estimation technique that the area which has a high cluster density is near the actual leaking area.

Conclusion

A new leakage detection method which can estimate the position of the leakage of the boiler tube in the power generation equipment in its initial stage was studied and developed and was applied to a coal power generation station with the capacity of 500MW. As a result, the boiler leakage can be detected in the initial stage and the leakage position can be correctly estimated. So, this new method can shorten the down time of the power plant and increase the efficiency of the power plant facilities. The results are summarized as follows. In this study, the 3D point location technique is developed using size ratio of RMS signals from the measuring sensors in order to solve the limit which the existing time difference method can not overcome.

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