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Conceptual Design of a Leak Detector Using Audio and Video Captures

Bo Gyung Kim and Gyunyoung Heo*
Kyung Hee University, 1 Seocheon-dong, Giheung-gu, Yongin-si, Gyeonggi-do, 446-701, Korea
** Corresponding author: gheo@khu.ac.kr*

1. Introduction

This study proposes a conceptual idea for improving the detection and the monitoring capabilities of the leak before break (LBB), which is based on vision and acoustic camera technology. The notion of the LBB is used in the nuclear power plants (NPPs) to describe the situation that a leak will take place before a catastrophic break occurs in the piping carrying the high energy coolant. [1] This concept has resulted from extensive research, development, and rigorous evaluations by regulatory authorities and utilities since the early 1970s. [1, 2] Regulatory Guide 1.45 which was issued in 1973 or its revised document, DG-1173 which was issued in 2007 recommends a couple of mandatory as well as optional methodologies for effective detecting the LBB. [3, 4] The technical specifications in those documents require the NPPs should secure at least two independent and diverse instruments and/or methods that have the detection and monitoring capabilities for the LBB. Monitoring of both sump flow and radioactivity of airborne particulate should be mandatory. In addition to the monitoring systems specified in the technical specifications, others should be used to detect and monitor for leakage. These supplemental instruments/methods may include, but are not limited to, the following:

- Condensate flow rate from air coolers
- Airborne gaseous radioactivity
- Containment humidity
- Containment temperature
- Containment pressure
- Acoustic emission
- Video surveillance.

Including those technologies, the leakage monitoring systems should be also equipped with provisions to permit calibration and testing during plant operation to ensure functionality or operability, as appropriate. It should be noted that no single leak detection method currently available combines optimal detection sensitivity, location ability and measurement accuracy. The technology is available to improve leak detection capability at specified sites by use of acoustic emission monitors or moisture sensitive tape. However, current acoustic emission techniques still have difficulties with source discrimination and leak rate information. Moisture sensitive tape provides neither quantitative information on leak rate nor specific information on the location other than the location of the tape. [2]

This study proposes a leak detector using vision and acoustic techniques, which is expected to discriminate leak sources as well as to quantify the leak rate.

2. Methods and Results

2.1. Overall Concept

The Vision and Acoustic Camera Leak Sensor (VACLS), which is the synergetic combination of vision camera and acoustic camera, is shown in Figure 1. Figure 2 show the principle of the VACLS operation. The acoustic camera takes role of detecting and locating a leak source. The acoustic camera let the vision cameras focus on the location of the leakage. The vision camera automatically (or sometimes manually) zooms in the location of the leakage, which should be helpful for operators to recognize the accident. In addition, a numerical algorithm to estimate the leak rate is provided. In order to capture the images enough to achieve the high accuracy of predicting leak rate, the vision camera and/or the acoustic camera are movably mounted, for example, on a rail or a joint pole.

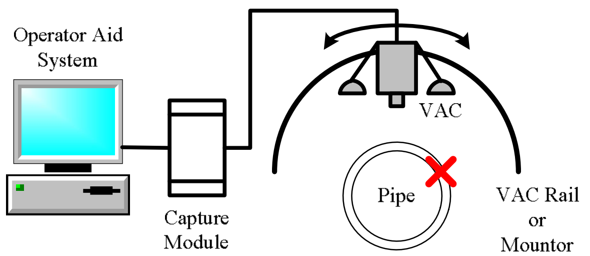

Figure 1. Overall concept of a vision and acoustic camera leak sensor

2.2. Acoustic Camera

The Acoustic Camera (AC) is a shape of parabola antenna on which a multiple connector sockets are helically installed. A number of microphone arrays are arranged in a connector socket. This arrangement is not only able to detect the location of leakages by using triangulation method, but also effective to eliminate directional noise and background noise so that the AC ultimately provides the information of whether or not there is any leakage and the location of the leakage, if any, with the vision cameras. [5] The capability of capturing the location of a noise source named this equipment to 'camera.'

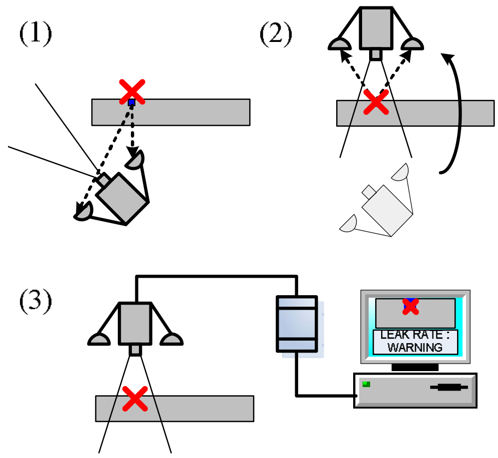

Figure 2. Detecting and monitoring leakage using a VACLS

2.3. Vision Camera

The application of video surveillance is well known in industries. The vision camera (VC) is a non-touch analysis equipment for machine/process control or information acquisition with a proper image processing. While the AC is able to catch information of leakage location, the vision camera (VC) actually provides the image of the leakage and, if possible, the expected value of leak rate. The focal point of a VC is controlled by the information provided by the AC. The lens of a VC can aim at a specific point by bending the body of the VC and zoom in and out the image delivered to operators. Figure 3 shows the concept of the VC mounted on the AC.

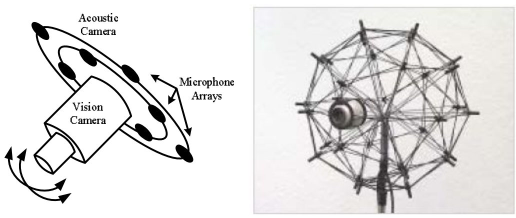

Figure 3. Video camera mounted on acoustic camera (left) and a commercial product of acoustic camera (right)

2.4. Operator Aid System

The operator aid system is a human-machine interface providing the captured images of the leakage and the leak rate. Figure 4 shows the numerical algorithm executed in the operator aid system.

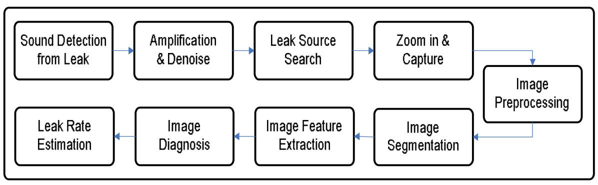

Figure 4. Flowchart for video and audio image processing

The main part of acoustic image processing is composed of 1) amplification, 2) elimination of background noise, and 3) triangulation method. This input is given to the focal point controller of a VC. If the focal point of the VC and the location of an acoustic source fall in an error bound, the VC start capturing the images. The vision image processing is typically divided into 1) the active method which is applied in case that there is no prior-knowledge on input patterns and 2) the passive method which is applied to cases that the prior-knowledge is available. [6] Even though the passive method is preferred to get high accuracy, this may be different according to the detailed design of a VACLS.

The result of the vision image processing is used to quantify leak rate. The leak rate is expected to be a function of 1) the pixel distribution of the vision image, 2) the operating conditions inside piping, and 3) the design of piping. The leak rate estimation can be based on an analytic model or an empirical model integrating thermo-hydraulic models with experimental data.

3. Conclusions

In this study, the conceptual idea of a VACLS was made a sketch, and some literature surveys were performed to check up the feasibility of the idea. Since a video technique is vulnerable to focus on leak points and an acoustic technique is weak to distinguish the leakage source and to quantify leak rate, their combination is expected to complement the other side's shortcomings. However, the detailed design should consider the radioactive resistance, the covering capability of anticipated leakage locations, the sensor sensitivity and maintainability, the accuracy or uncertainty in estimating leak rate of the VACLS. We are making a plan to develop a demonstrative mock-up.

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