System for Steam Leak Detection by using CCTV Camera

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1. Introduction

There are many pipes in the secondary cooling systems of nuclear power plants and coal-fired power plants. In these pipes, high pressure fluids are moving with at high velocity, which can cause steam leakage due to pipe thinning. Steam leakage is one of the major issues for the structural fracture of pipes. Therefore, a method to inspect a large area of piping systems quickly and accurately is needed. Steam leakage is almost invisible, because the flow has very high velocity and pressure. Therefore, it is very difficult to detect a steam leakage. In this paper, we proposed the method for detecting steam leakage using image signal processing. Our basic idea comes from a heat shimmer, which shines with a soft light that looks as if it is being shaken slightly. To test the performance of this technique, experiments have been performed for a steam generator. Results show that the proposed technique is quite powerful for steam leak detection.

2. Methods and Results

2.1 Detecting algorithm

Because steam has very high temperature and pressure when it is leaked from the pipe of a nuclear power plant, we can see a glimmer in the background image. This is the heat shimmer, which is generated because the index of the refraction of light is different with the temperature of the air. Thus, we proposed a technique for leak detection using a heat shimmer.

If a leakage occurs, vapor or water leaks out, and the backward background haunts by the hot heat, and a minute change is generated in the camera images. If the image change can be sensed, a leakage will be able to be detected using the camera images. To find the change of an image taken by a camera, the image signal at the stationary state and the leakage image have to be compared.

2.2 Experimental for detecting steam leakage

To verity the proposed method, we have performed an experiment for detecting steam leakage of high temperature and pressure. Fig. 1 shows the experimental setup. Steam was made by a steam generator, where the internal temperature and pressure were 150℃ and 6atm.

Fig. 2 shows the experimental results. In the case of leaking steam in a real nuclear power plant and in a thermoelectric power plant, it cannot be seen by the naked eye, as shown in Fig.2(a). This is because the temperature and pressure of the leaking steam are very high.

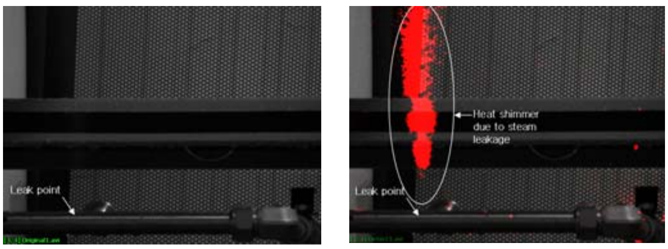
(a) (b)

Fig. 1 Experimental setup for detecting steam leakage Camera and image processing computer, Steam generator

The experimental results of this situation are shown in Fig. 2. In the original image, as shown in Fig.2(a), the steam leaking out cannot be observed, but we can see the steam leakage very well in the results in Fig.2(b), which applied the proposed image signal processing. The resulting image is shown overlapping the image processing results (red area) of the original image.

Next, we try to find a steam leakage in an insulated pipe, because the pipes in nuclear power plants are surrounded by insulation. The experimental setup is same as in Fig. 1. The test pipe is surrounded by insulation, as shown in Fig.3 (a).

The experimental results are shown in the Fig. 3. We cannot find the steam leak in the original image (Fig. 3 (a)), but it is easy to find it in the resulting image using the proposed method as shown in Fig.3(b).



(a) (b)

Fig. 2 Experimental result for invisible steam, (a) Original image, (b) Detected steam by using image signal processing

(a) (b)

Fig. 3 Experimental result for insulated pipe, (a) Original image, (b) Detected steam by using image signal processing

2.3 Error correction

There is vibration of a wall or floor on the power plant due to vibrating source such as a turbine, flow and so on.

If a camera oscillates as shown in Fig. 4, we cannot measure steam leakage exactly.

Fig. 4. Camera mounted on a pen-tilt

To correct the error due to camera oscillating, we used to normalized cross correlation as explained in Fig. 5.

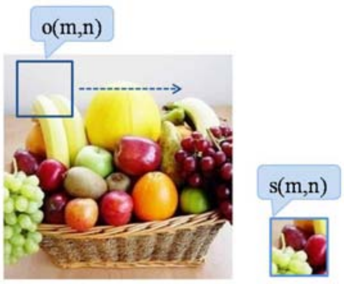
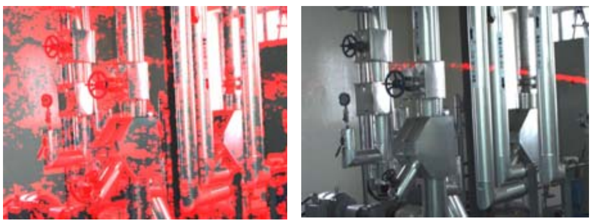


Fig. 5 Normalized Cross Correlation



(a) (b)

Fig. 6 When the camera oscillated with 3Hz, (a) the result of steam leak detection before correcting, and (b) the result after correcting error due to camera shaking.

When the camera oscillated with 5Hz, Fig. 6 shows the experimental results before and after correcting error. The results show that we can detect the steam leakage exactly when the error due to vibration of the camera is compensated.

3. Conclusions

In this research, a leakage discrimination method using a camera image signal at nuclear power plant piping was proposed. When high-temperature vapor is leaked out, the proposed method can detect the steam using heat shimmer.

To find the change in an image taken by a camera, the image signal at the stationary state and the leakage image have to be compared. By reducing the image noise from the two different images, we can obtain a clear image of the heat shimmer.

To verify the proposed method, experiments have been performed for the steam generator. The results show that the proposed technique is quite powerful in the detection of steam leakage

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