Experimental evaluation of the wall-thinned defects using IR thermography

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1. Introduction

Local wall thinning is the main degradation mechanism of carbon steel piping components in nuclear power plants (NPPs), resulting from flow accelerated corrosion (FAC). Local wall thinning reduces the failure pressure, load-carrying capacity, deformation ability, and fatigue resistance of piping components [1-3]. Therefore, the appropriate integrity assessment procedure is required. From past several decades, there have been lots of nondestructive inspection technologies widely. On the other hand, thermography method in these nondestructive testing (NDT) has recently expanded its application range gradually with the development of vision technology. The infrared thermor graphy which is one of these techniques provides real-time images by scanning the temperature of the target surface and then, converting it to the temperature [4]. Though observation of the temperature difference this technique can assess the appropriated integrity of carbon steel piping.

2. Theoretical background

2.1 Infrared Themography

When a specific carbon steel piping is heated from outside, thermal diffusion is changed by interruption of defect in carbon steel piping, resulting in the temperature difference on the surface of target. The infrared thermography technique can predict the shape and location of the defect in the carbon steel piping by analyzing the temperature distribution on the surface.

2. Experimental Equipment and Methods.

3.1 Specimen

In this experiment, the pipe specimen was processed with the defects in pipe inner walls. 4 inch diameter-pipe specimen using the Shc. 80 ASTM A106 Gr.B material such as the actual NPPs materials was manufactured. As shown in Fig. 1, the square type defects with various depth are provided artificially to specimen that has size of full-length (l) 500mm, thickness (t) 7.5 mm and diameter (D_0) 113 mm. Four defect with L/D_0 = 0.5 (L=56.5mm) are processed in the specimen.

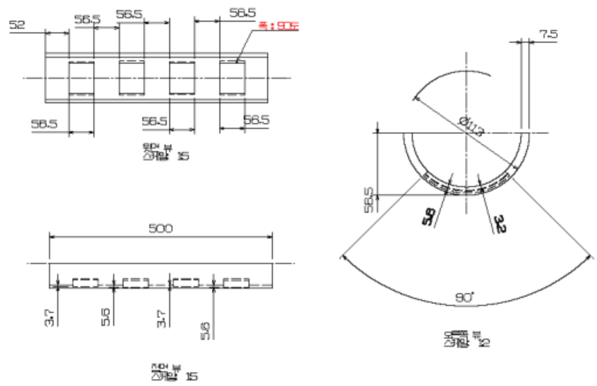


Fig. 1 Specimen

3.2 Simulation Method

To carry out this study, the 1 kW halogen lamps were chosen as heating element. To control the distribution of luminous intensity on the surface of specimen by 1 kW halogen lamps, LightTools based on lay-trace was used. To improvement of uniformity of luminous intensity, we design the reflector and the cylindrical lens by optimizing the focal length. The distance between the halogen lamps and specimen was fixed to 1m.

3.3 Experimental Methods

The temperature of the piping system maintains the room temperature during the maintenance period of NPPs. Thus, this experiment was done in room temperature.

The experimental equipment consists of the IR camera (FLIR Silver 480M), two halogen lamp (1kW) and a PC.

The distance between the specimen and the IR camera was fixed at 1m, and the distance between the halogen lamps and specimen was change from 1m to 3m for optimization of defect images. The intensity of 1kW halogen lamp was set to 70 %.

The experiment was carried out in the sealed room to eliminate the effect of ambient temperature and humidity.

4. Result

Figure 2 shows the simulation result of the distribution of luminous intensity on the surface of specimen by heating elements with and without cylindrical lens. Without cylindrical lens, the light is focused on the center of specimen while with cylindrical lens the light is spread the whole specimen. This can be expected to the improvement of detection of size and shape of defects.

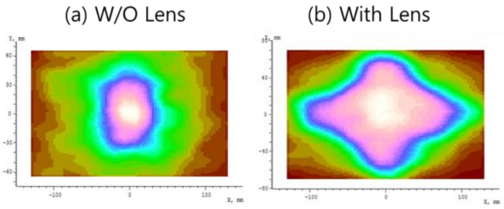


Fig 2. Distribution of luminous intensity on the surface of specimen by heating elements with and without cylindrical lens

Figur 3 shows the effect of focal length on the distribution of luminous intensity on the surface of specimen by heating elements with cylindrical lenses. With decreasing the focal length from 771 to 428 mm, we found that the light is more spread along to horizontal direction, resulting in improvement of uniformity of the distribution of luminous intensity.

Table 1. Distribution of luminous intensity on the surface of specimen by heating elements with various focal length cylindrical lenses

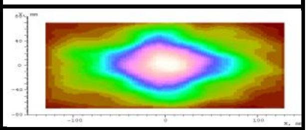
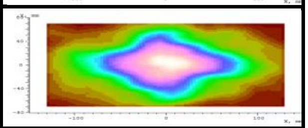
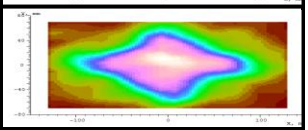
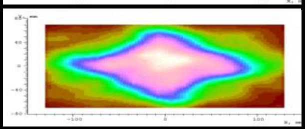
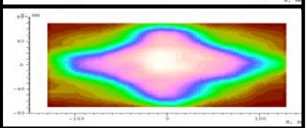
	Curvature	**Focal length**	**Result**
1	**0.026**	**771mm**	
2	**0.027**	**643mm**	
3	**0.028**	**559mm**	
4	**0.029**	**482mm**	
5	**0.030**	**428mm**	

Figure 3 shows the IR images measured in the pipe specimen according to the distance between halogen lamp and specimen. The cylindrical lens was designed with focal length of 482 mm. The defects were identical for all of the test conditions. We found the clear defect images when the distance between halogen lamp and specimen is 2m.

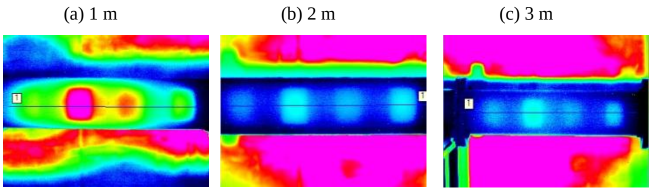


Fig. 3. IR images of defective pipe specimen

Figure 4 shows the IR images measured in the pipe specimen with and without lens. With the use of cylindrical lens, the detection of defects is significantly improved as shown in Fig 4 (b).

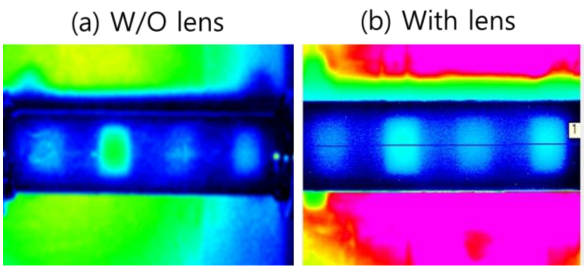


Fig. 3. IR images of defective pipe specimen with and without cylindrical lens

3. Conclusions

In this study, the infrared thermography technique was applied to detect the wall-thinned defects. To get the uniform distribution of luminous intensity on the surface of specimen by heating elements, we design the cylindrical lens with focal length of 482 mm. With the use of cylindrical lens, clear defect images were detected by infrared thermography technique

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