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Estimation of wall thinning defect size and location in pipes by Laser Speckle Interferometry

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Abstract

Piping in the Nuclear Power plants (NPP) are mostly consisted of carbon steel pipe. The wall thinning defect is mainly occurred by the affect of the flow accelerated corrosion (FAC) of fluid which flows in carbon steel pipes. This type of defect becomes the cause of damage or destruction of piping. Therefore, it is very important to measure defect which is existed not only on the welding part but also on the whole field of pipe. Over the years, Laser Speckle Interferometry (LSI) has been used as non destructive testing methods of the various kinds of materials. This technique has many merits and used for various industrial fields. In this paper, the quantitative analysis results of the location and the size of wall thinning defect that is artificially processed inside the carbon steel pipe by using LSI are obtained. The result obtained from no defect specimen and a series of the specimens with defect (according to the radial width and the axial length of defect) are compared with the strain distribution differences. This result can be used in defect size estimation of the carbon steel pipe. Experimental results for carbon steel pipes with artificial wall thinning defect show good agreement with actual values.

Keywords: Wall thinning defect, Quantitative analysis, Strain distribution, Shearography

1. Introduction

There are some optical non-destructive testing methods based on the laser speckle method including the electronic speckle pattern interferometry (ESPI) and the shearography. These speckle methods do not require any special pre-processing and may measure the deformation and the strain arising on the whole interesting area in real time. ESPI can measure the deformation precisely. However, because it is very sensitive to the external noise and vibration, ESPI has to be applied to the practical industrial field only with the optical table to isolate the external vibration or the vacuum chamber [1-3]. The shearography, another technique using the speckle method, measures the slope of the deformation by appropriately organizing the optical-interferometer so that it does not require the optical table, and is very excellent to measure the defect of an object. And on the basis of its strength in external noise and vibration, it is most widely used in the detection technique for inner defect of an object in the industrial field.

In this study, the quantitative analysis results of the location and the size of wall thinning defect that is inside the carbon steel pipe are obtained by using Shearography. The result obtained from no defect specimen and a series of the specimens with defect are compared with the strain distribution differences.

2. Principle of Shearography

As shown in Fig. 1, when an object is irradiated by a divergence light, beam reflected on the surface of an object is divided by a beam splitter into two beams. One beam is imaged to the image plane after the reflection on the Mirror 1 and the other beam is imaged to image plane after the reflection on the Mirror 2 which can be tilted. At this time, if Mirror 2 is tilted, the wave-front reflected on the Mirror 2 is formed and it makes an image sheared to an image formed by beam reflected on the Mirror 1. The interference fringe pattern resulted from two-beam interference presents the slop of the out-of-plane deformation of an object occurred after the deformation.

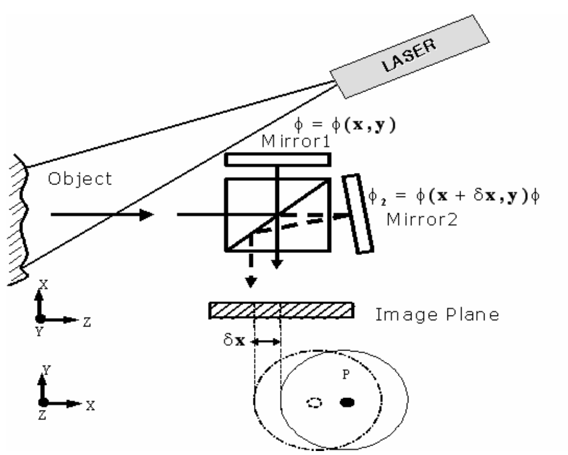


Fig. 1 Speckle pattern shearing interferometry

δx expresses the tilted angle and it is called shearing or shearing amount. Formation of interference fringe pattern can be controlled by shearing and shearing direction. Eqn. (1) expresses difference between d and d'[4]. $\vec{n}_0$ is the unit vector of irradiation direction and $\vec{n}_s$ is the unit vector of observation direction.

$$\Delta\phi = \frac{2\pi}{\lambda}(\vec{n}_0 - \vec{n}_s)\cdot(d - d') \qquad (1)$$

If the incident direction of the laser beam irradiated to the object is the same as the vertical observation direction, eqn. (1) can be re-rewritten as eqn. (2).

$$\Delta\phi = \frac{4\pi}{\lambda}\Delta d \qquad (2)$$

Δd is expressed to eqn. (3) by using Taylor series. The deformation of x direction is depended on the shearing amount Δx. The high order terms of right side in eqn.(4) is very small so more than second term can be ignored. Therefore eqn. (2) is expressed as eqn. (4) by eqn. (3).

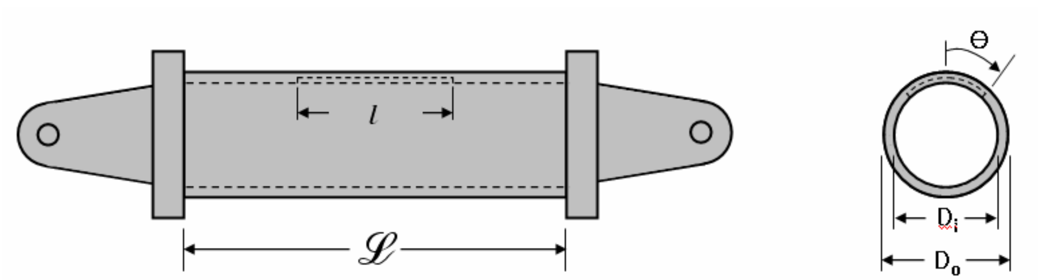
$$\Delta d = \frac{\partial d}{\partial x}\frac{\Delta x}{1!} + \frac{\partial^2 d}{\partial x^2}\frac{(\Delta x)^2}{2!} + \Lambda \qquad (3)$$

$$\Delta\phi = \frac{4\pi}{\lambda}\left(\frac{\partial d}{\partial x}\right)\Delta x \qquad (4)$$

3. Experiment

Fig. 2 shows the shape and dimension of specimen. ASTM A106GrB, pressure specimen with yield strength 240MPa, tensile strength 415MPa, the elongation of length direction 30% was used. The inside defect of specimen was artificially made the same as Table 1.

In this paper, Shearography use to measure defect of straight pipe by internal pressure change. At first, the non-defect specimen was measured to compare measurement result according to existence of defect. And, the specimen with defect was measured. The wall thinning defect of straight pipe inside measured out-of-plane deformation to each pressure by constant pressure. At this time, shearing amount was 10 pixels in x, y direction.



* Length of pipe(L)=342.00mm

* External diameter(D_o)=113.40mm

* Inside diameter(D_i)=99.00mm

Fig. 2 Shape and dimension of pipe specimen

Table.1 Type of Specimens

1. Specimen with no defect

ID No.	Defect Length l (mm)	Defect Width (2θ)	Minimum Thickness t_p (mm)
SSP-0A	0.00	0^o	7.2

2. Series of specimen according to minimum thickness

ID No.	Defect Length l (mm)	Defect Width (2θ)	Minimum Thickness t_p (mm)
SSP-2E	113.40	90^o	6.3
SSP-2F	113.40	90^o	5.4
SSP-2G	113.40	90^o	3.6
SSP-2H	113.40	90^o	1.8

3. Series of specimen according to defect width

ID No.	Defect Length l (mm)	Defect Width (2θ)	Minimum Thickness t_p (mm)
SSP-2D	113.40	45^o	1.8
SSP-2H	113.40	90^o	1.8
SSP-2L	113.40	135^o	1.8
SSP-2P	113.40	180^o	1.8

4. Series of specimen according to defect length

ID No.	Defect Length l (mm)	Defect Width (2θ)	Minimum Thickness t_p (mm)
SSP-1H	56.70	90^o	1.8
SSP-2H	113.40	90^o	1.8
SSP-3H	170.10	90^o	1.8
SSP-4H	226.80	90^o	1.8

4. Results and discussion

4.1 Specimen with no defect

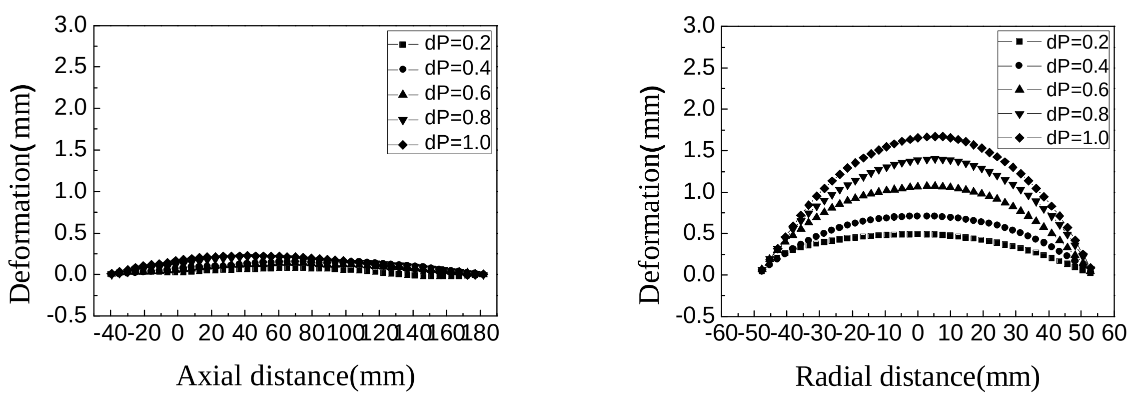


Fig. 3 Deformation results of specimen with no defect

As shown in Fig. 3, the diameter of pipe in radial direction was increased according to increment of pressure; the pipe in axial direction was happen slight shaking according to increment of pressure. According to the measure result of no defect specimen, we were estimate the size of wall thinning defect, compare to strain distribution of specimen with defect.

4.2 Specimen according to minimum thickness

Fig.4 shows the testing result of specimen according to thickness. As shown in Fig.4, the more thickness thin, size (length) of wall thinning defect part is clearly obtained in axial direction. And the more thickness thin, deformation was increased in radial direction. However, radial defect width was not measured in spite of thickness decrement.

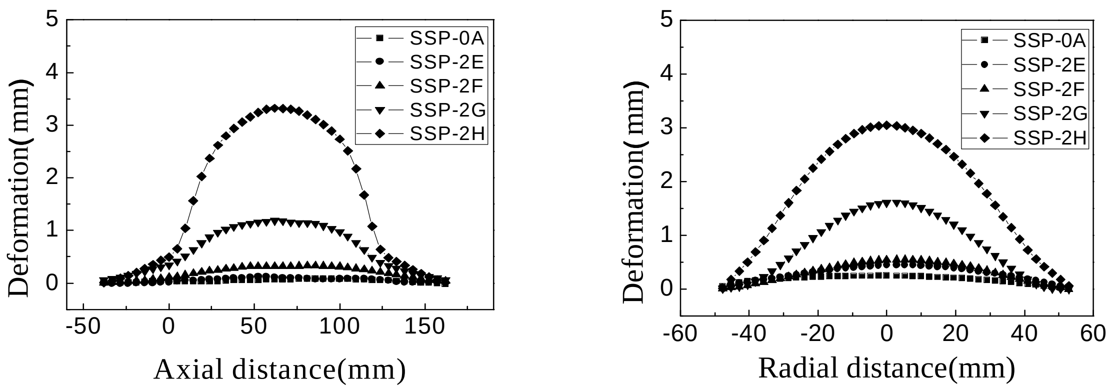


Fig. 4 Deformation results according to minimum thickness

4.3 Specimen according to defect width

Fig. 5 shows the deformation result of the specimen which follows in defect width. From experimental result, the more the width of the defect is narrow, the more the deformation is concentrated in defect area and the more the width of the defect is wide, shape of deformation is similar to the flat board. The length of defect is regularly measured about the 10mm without regard to width of defect.

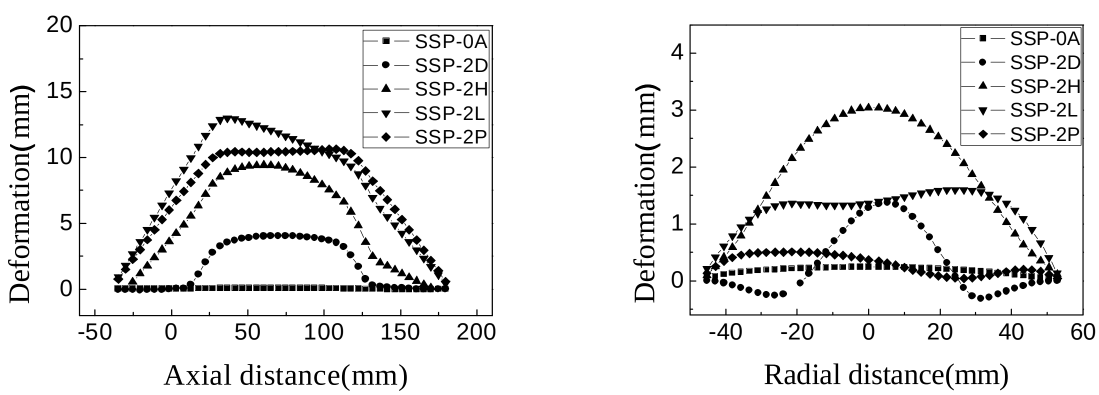


Fig. 5 Deformation results according to the defect width

4.4 Specimen according to defect length

Fig. 6 shows the deformation results according to the defect length. Measurement experimental result, defect length of each specimen was accurately measured. (SSP-1H : 57mm, SSP-2H : 120mm, SSP-3H : 190mm, SSP-4H : 225mm) But the deformation distribution of radial direction according to length of defect showed in little by little different shape.

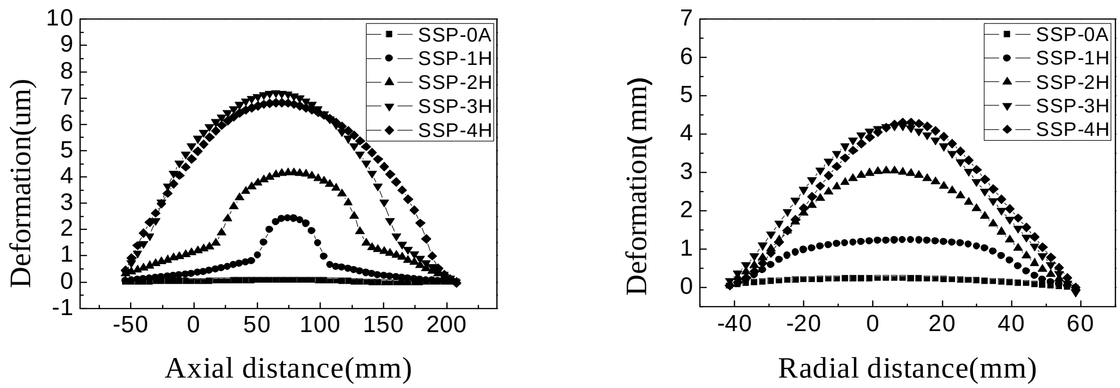


Fig. 6 Deformation results according to the defect size

5. Conclusions

In this paper, the size of wall thinning defect was estimated by measured deformation distribution by using Shearography. From the result, it was accurately measured that length of wall thinning defect which is located on the pipe inside. But it was impossible to estimate width of defect because the shape of deformation distribution of radial direction is not regularly. Therefore a more research is necessary about this substance.

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References

[1] Baik, S.H., Park, S.K. and Kim, C.J., “Applications of speckle interferometer”, Journal of the Korean Society of Precision Engineering, Vol.21, No.5, 2004, p14-18

[2] Kang, Y.J., Lee, J.S., Park, N.K. and Kwon, Y.K., “Ideal phase map extraction method and filtering of Electronic Speckle Pattern Interferometry”, Journal of the Korean Society of Precision Engineering, Vol.19, No.12, 2002, p20-26

[3] Kim, K.S., Kang, K.S., Kang, Y.J., Jeong, S.K., “Analysis of an internal crack of pressure pipeline using ESPI and Shearography”, Optics & Laser Technology, Vol.35, No.99, 2004, p639-643

[4] Lee, K. J., Chang, H. S., Jung, H. C., Kim, K. S., "Quantitative out-of-plane deformation

Measurement of pressure Vessel with the Defect using shearography". Journal of the Korean Society for Precision Engineering, Vol. 23, No.10, 2006, pp. 36-43