Nucl Eng Technol 47 (2015) 115–125

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.journals.elsevier.com/nuclear-engineering-and-technology/

Original Article

RESIDUAL STRESS MEASUREMENT ON THE BUTT-WELDED AREA BY ELECTRONIC SPECKLE PATTERN INTERFEROMETRY

KYEONGSUK KIM [a], TAEHO CHOI [b], MAN GYUN NA [c], and HYUNCHUL JUNG [a,*]

[a] Department of Mechanical System Engineering, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju 501-759, Republic of Korea
[b] Department of Mechanical System Engineering, Graduate School, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju 501-759, Republic of Korea
[c] Department of Nuclear Engineering, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju 501-759, Republic of Korea

ARTICLE INFO

Article history:
Received 9 April 2014
Received in revised form
29 August 2014
Accepted 23 September 2014
Available online 21 January 2015

Keywords:
Butt-Welded Area
Elastic Modulus
Electronic Speckle Pattern Interferometry
Phase Difference
Residual Stress
Stress Distribution

ABSTRACT

Background: Residual stress always exists on any kind of welded area. This residual stress can cause the welded material to crack or fracture. For many years, the hole-drilling method has been widely used for measuring residual stress. However, this method is destructive. Nowadays, electronic speckle pattern interferometry (ESPI) can be used to measure residual stress with or without the hole-drilling method. ESPI is an optical nondestructive testing methods that use the speckle effect. Mechanical properties can be measured by calculation of the phase difference by the variation of temperature, pressure, or loading force.
Methods: In this paper, the residual stress on the butt-welded area is measured by using ESPI with a suggested numerical calculation. Two types of specimens are prepared. Type I is made of pure base metal part and type II has a welded part at the center. These specimens are tensile tested with a material test system. At the same time, the ESPI system was applied to this test.
Results: From the results of ESPI, the elastic modulus and the residual stress around the welded area can be calculated and estimated.
Conclusion: With this result, it is confirmed that the residual stress on the welded area can be measured with high precision by ESPI.
Copyright © 2015, Published by Elsevier Korea LLC on behalf of Korean Nuclear Society.

1. Introduction

Residual stress, or internal stress, is usually defined as the stress that remains in mechanical parts that exist in the bulk of a material without the application of an external load (including gravity), or other sources of residual stress, such as a thermal gradient [1]. They may be created by manufacturing processes such as casting, rolling, welding, heat treating, or forging, or may occur during the life of a structural or mechanical component [2,3]. The magnitude and

* Corresponding author.
E-mail address: yonggaryjung@gmail.com (H. Jung).
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
http://dx.doi.org/10.1016/j.net.2014.09.001
1738-5733/Copyright © 2015, Published by Elsevier Korea LLC on behalf of Korean Nuclear Society.

distribution of residual stresses are highly significant and need to be quantified since the mechanical behavior of different materials will be affected when they are present.

There are a number of different methods for measuring residual stress. These methods can be divided into two parts, the destructive method and the nondestructive method [4]. Hole drilling, ring coring, deep hole drilling, the slitting method, and the contour method can be included in the destructive method, whereas X-ray diffraction, neutron diffraction, magnetic method, ultrasonic method, and optical methods are included in the nondestructive method.

The hole drilling method is the most widespread technique for measuring residual stresses. This technique involves monitoring the strains generated by the relieved stresses when a small hole is drilled into a stressed material. These strains are usually measured by means of strain gage rosettes. However, it has some practical and economical drawbacks. For instance, the hole must be drilled in the center of the rosette since misalignments can cause significant errors. This method is also a destructive testing method.

The difficulty can be overcome using optical techniques. Among them, electronic speckle pattern interferometry (ESPI) is a technique that is very attractive in optical metrology not only for its noncontact nature but also for its relative speed. This is mainly due to the use of video detection and digital image processing [5,6]. The application of digital techniques in ESPI allows the automation of the data analysis process, which is usually based on the extraction of the optical phase distribution encoded by the generated correlation fringes. From these data, in-plane displacement fields can be measured over the whole surface of any rough object without making contact with it. Unwrapped phase distribution is useful because it allows direct whole field evaluations of residual stresses [7,8].

In this paper, deformations of the base metal and welding part of butt-welded specimens are measured by using in-plane displacement sensitive ESPI. Young's modulus of base metal and the welding zone are determined from the result of ESPI. The residual stress distribution of butt-welded specimens can also be estimated from the strain profile of ESPI and Young's moduli. This is contrasted with other analysis methods. The presented method offers an improved speed of evaluation due to the elimination of the surface preparation time of the hole-drilling technique.

2. Materials and methods

2.1. ESPI

Laser has high coherence characteristics as two or more waves can be interfered in the coherence length. When an optically rough surface of an object is illuminated by a coherent laser beam, the beam is scattered in all directions. These scattered laser beams are interfered by each other and the intensity of each point on an image obtained by a charge-coupled device camera varies randomly. This phenomenon is well known as the speckle effect. ESPI measurement using a laser uses this speckle phenomenon so that the displacement of an object by the deformation can be measured.

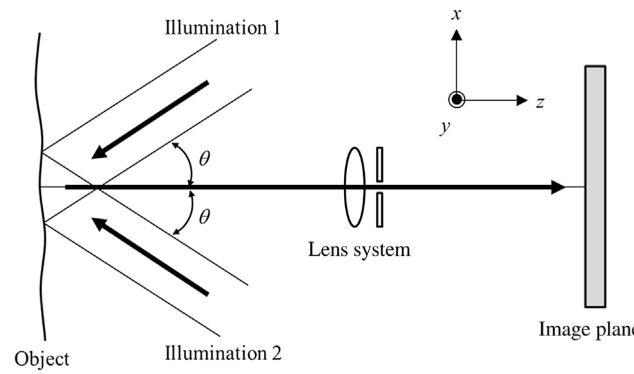

Fig. 1 – Schematic of in-plane displacement sensitive interferometer.

Fig. 1 shows a schematic of an in-plane displacement sensitive interferometer. Two laser beams are illuminated with the same angle θ on the surface of an object at the same time. Illuminated beams form the speckle pattern on the surface of an object, and these speckle patterns are interfered to form another speckle pattern. This pattern is formed by the phase difference of illuminated beams. When the path of the laser beam can be traced, the relationship between the laser beam and the phase can be shown as follows:

$$\Delta\phi = \delta_1 - \delta_2 = \frac{4\pi}{\lambda} d_x \sin\theta_i \quad (1)$$

where: δ_1 = optical path length of beam 1; δ_2 = optical path length of beam 2; λ = wavelength of a laser; d_x = x-axis component of sensitivity vector d; and θ_i = angle between illumination direction and normal direction to surface.

The path of a laser beam between the laser source and the image plane or charge-coupled device camera in one direction is shown in Fig. 2. In Fig. 2, d is the sensitivity vector of this interferometer and θ_i is the angle between the illumination direction and the normal direction to the surface of an object; θ_d the angle between the sensitivity vector and the normal direction to the surface of an object, and θ_v an angle between the viewing direction and the normal direction to the surface of an object. As an interference fringe pattern is formed by δ_1 and δ_2, the optical path lengths of the two beams and the phase difference can be written as Equation 1.

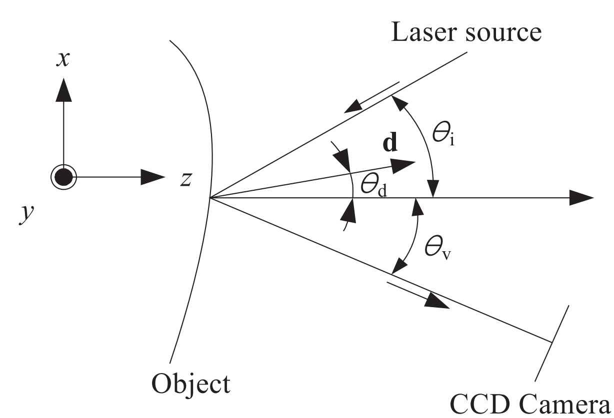

Fig. 2 – Optical path difference as the object deformation.

Download English Version:

https://daneshyari.com/en/article/1740196

Download Persian Version:

https://daneshyari.com/article/1740196

Daneshyari.com