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Donald M. Boyd
William W. Wilcox

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Lawrence Livermore Laboratory

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Donald M. Boyd
William W. Wilcox
Materials Engineering Division
Lawrence Livermore Laboratory*

Abstract

Waist welds on spherical experimental pressure vessels have been evaluated under pressure using holographic interferometry. A coincident viewing and illumination optical configuration coupled with a parabolic mirror was used so that the entire weld region could be examined with a single hologram. Positioning the pressure vessel at the focal point of the parabolic mirror provides a relatively undistorted 360 degree view of the waist weld. Double exposure and real time holography were used to obtain displacement information on the weld region. Results are compared with radiographic and ultrasonic inspections.

Key words: holography, pressure vessels, welds, flaws, nondestructive testing

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Introduction

The nondestructive evaluation of waist welds on spherical pressure vessels is routinely made using ultrasonic and radiographic techniques. Detailed evaluation of the ultrasonic and radiographic results is often difficult and can require sectioning and metallographic evaluation to verify the nondestructive testing results. A third and complementary technique which has been found to be useful for evaluating welds is double exposure holographic interferometry.

The noncontact, wide field of view, surface displacement measurement technique of holographic interferometry has been successfully applied to the evaluation of pressure vessels under stress (1,2,3). The method has previously been suggested as a technique for measuring weld penetration in pressure vessels (4). Recent work has shown that a qualitative evaluation of a weld on a pressure vessel can be made (5). In this work a coincident viewing and illumination optical configuration has been used. One can view approximately 180^0 of the weld but only about the central 90 degrees gives useful information due to the part geometry. Several views are therefore normally required in order to ensure that full coverage of the we region is made during a holographic inspection.

A unique optical configuration, comprising of the placement of a pressure vessel in a parabolic mirror, has been devised which allows for 360 degree viewing of the waist weld in a single hologram (6).

This paper describes results for two spherical experimental pressure vessels evaluated both with and without the parabolic mirror arrangement. Results of the holographic tests are compared with ultrasonic "C" scans and radiographic inspections of the waist weld.

Test Procedure

Pressure testing of the vessels was performed in a modified high pressure cell. This cell is designed for both remote double exposure and real-time holographic testing of a variety of pressure vessels. Both the aluminum vessels described here are 76 mm diameter with a wall thickness of 3.8 mm. Low-pressure testing using inert gas was employed. The weld on these vessels is of the step variety with full penetration being 3 mm.

Two optical configurations were used to view these waist welds. The first test used a coincident viewing and illumination method (see Fig. 1). In order to cover the entire circumferential weld, the vessel was rotated for each pressure sequence. Double exposure holography was used to record the elastic behavior of the vessel between 0.17 MPa (25 psi) and 0.86 MPa (125 psi) for each viewing direction.

The second optical configuration couples a parabolic mirror with an almost coincident viewing and illumination arrangement. By placing the center of the vessel at the focal point of a parabolic mirror, the optical axis of the mirror can be aligned with the object beam and viewing direction to allow the entire waist weld to be viewed as shown in Fig. 2. Both double exposure and real-time holography were used to record the vessel displacement between 0 and 1.78 MPa (200 psi).

Results

Two identically designed spherical pressure vessels were tested using holographic interferometry. Figure 3 shows the double exposure interferograms for vessel A obtained by viewing the 0, 90, 180, and 270 degree locations. It is evident from the four views that the radial displacement behavior of the vessel is nonuniform around the weld circumference. Figure 4 is a double exposure interferogram obtained using the parabolic mirror on vessel A. In this configuration the entire weld is viewed simultaneously. The fringe density and the sharpness of the pointed fringe pattern at the weld for the parabolic mirror view both indicate nonuniform radial displacement around the weld.

Figures 5 which contains the 0, 90, 180 and 270 degree views for vessel B, show that there is much less variation in the radial displacement behavior. One draws the same conclusions from Fig.6 the parabolic mirror view of vessel B.

Comparing the results from the parabolic mirror test with the coincident viewing and illumination results shows that the same qualitative information is available using either technique. The advantage of the parabolic mirror is that a single view and pressurization provides the necessary information for evaluating the waist weld.

Real-time holography was also used to record the displacement of the two vessels in the parabolic mirror optical configuration. Figures 7 and 8 show successive photographs of the interference pattern during the pressurization of vessels A and B, respectively.

Radiographic and ultrasonic evaluations were also made on these two vessels. Radiography on vessel A showed incomplete penetration in one area near 0 degrees, and a distorted inner step resulting in a mismatch of the two hemispheres. The ultrasonic "C" scan of vessel A shown in Fig. 9 indicates an unfused root from 300 ^{o} through 45^{o}. In vessel B radiography revealed incomplete penetration throughout the weld length. The ultrasonic "C" scan for vessel B shown in Fig. 10

indicates an unfused root for the entire weld with the worst area located from 110^0 to 180^0. A white area on the C-scans indicates a "good" area in the weld.

There is good correlation between the holographic and ultrasonic results for the lack of fusion regions of both vessels. Comparing the ultrasonic "C" scan results with the parabolic mirror holographic interferograms a correlation is seen between the lack of fusion and the fringe density and the sharpness of the pointed fringe in the area of the weld The lack of fusion region for vessel A is located near 0 degrees. Figure 3a shows the resulting displacement caused by the unfused weld. A bending moment is present causing the vessel to displace more on either side of the weld line. The parabolic mirror view for vessel A (Fig. 4) shows a higher fringe density (number of fringes per unit length) around 0 degrees. Vessel B has unfused root around the entire weld; this is easily visible with either holographic technique.

The results of the real-time holography also correlate with the ulrasonic inspection. The worst area detected by the ultrasonic "C" scan, the 0^0 region of vessel A and the 145^0 region of vessel B, are the first areas where bending of the interference fringes is observed (see Figs. 7 and 8).

Conclusion

A qualitative evaluation of the welds on two spherical experimental pressure vessels has been made. The nondestructive testing techniques of radiography, ultrasonics and holographic interferometry were found to be complementary in that they give indications of the same weld condition. The type of weld flaw can only be established after metallographic sectioning. The two vessels described in this report will be sectioned in order to determine if the flaw type can be correlated with the detailed features of the holographic fringe pattern.

Quantitative evaluation of the holographic interferograms is another area being investigated. Computer raytracing techniques are being used to calculate an interferogram for comparison with real ones. This analysis of the parabolic mirror technique is expected to produce a reliable nondestructive evaluation method for circular waist weld evaluations.

Acknowledgments

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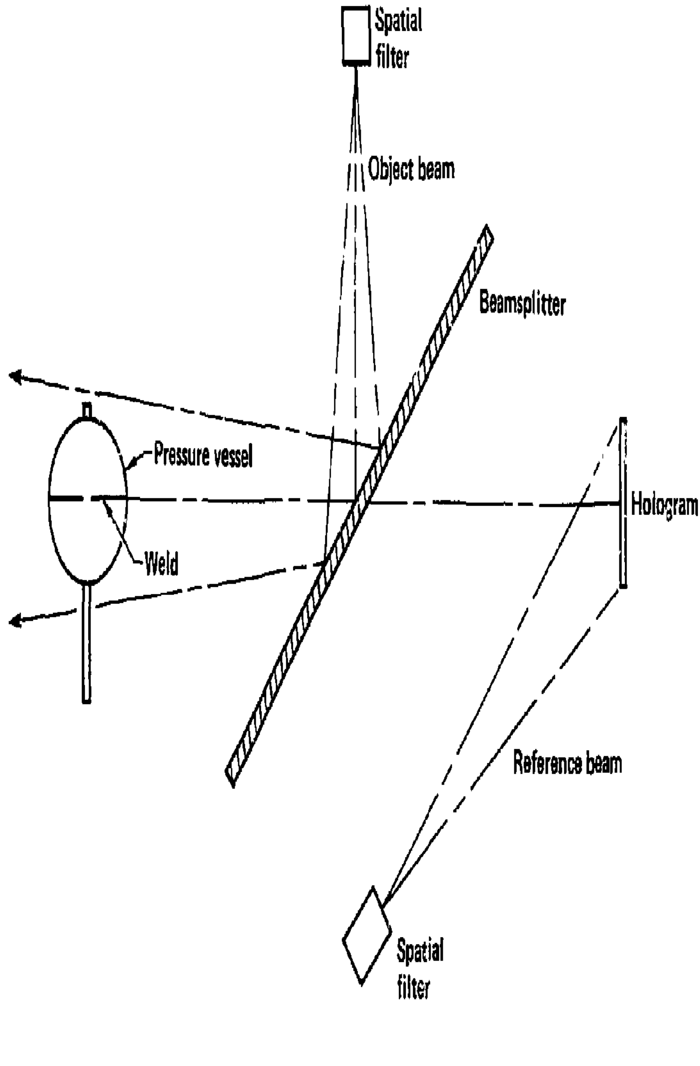


Fig. 1. Coincident viewing and illumination optical configuration for holographic interferograms of the pressure vessels.

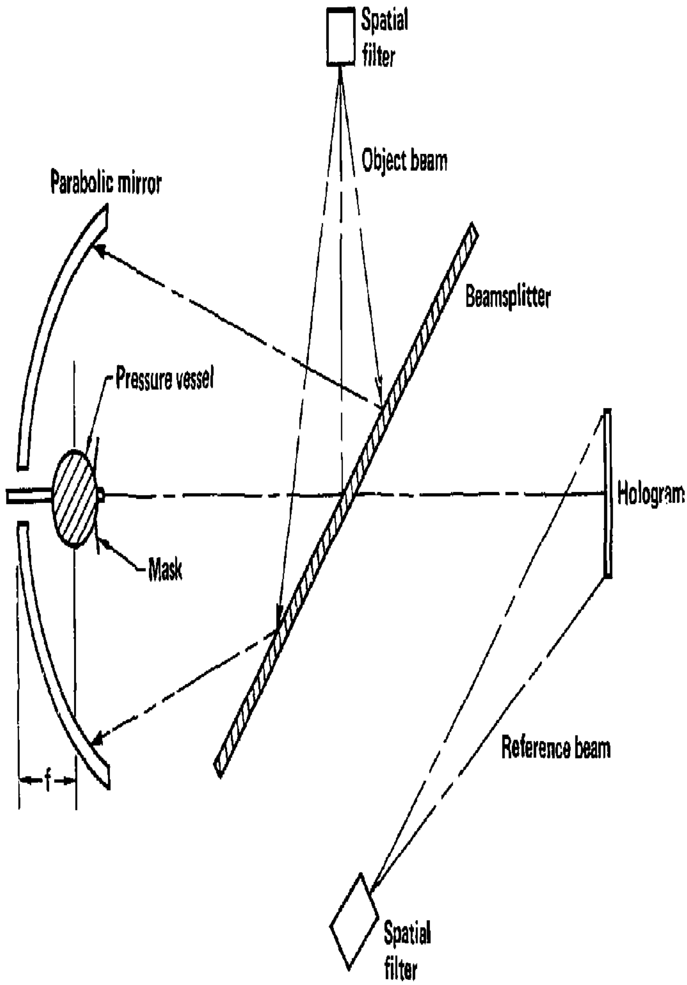


Fig. 2. Holographic optical configuration using a parabolic mirror to view 360 degrees of the waist weld.

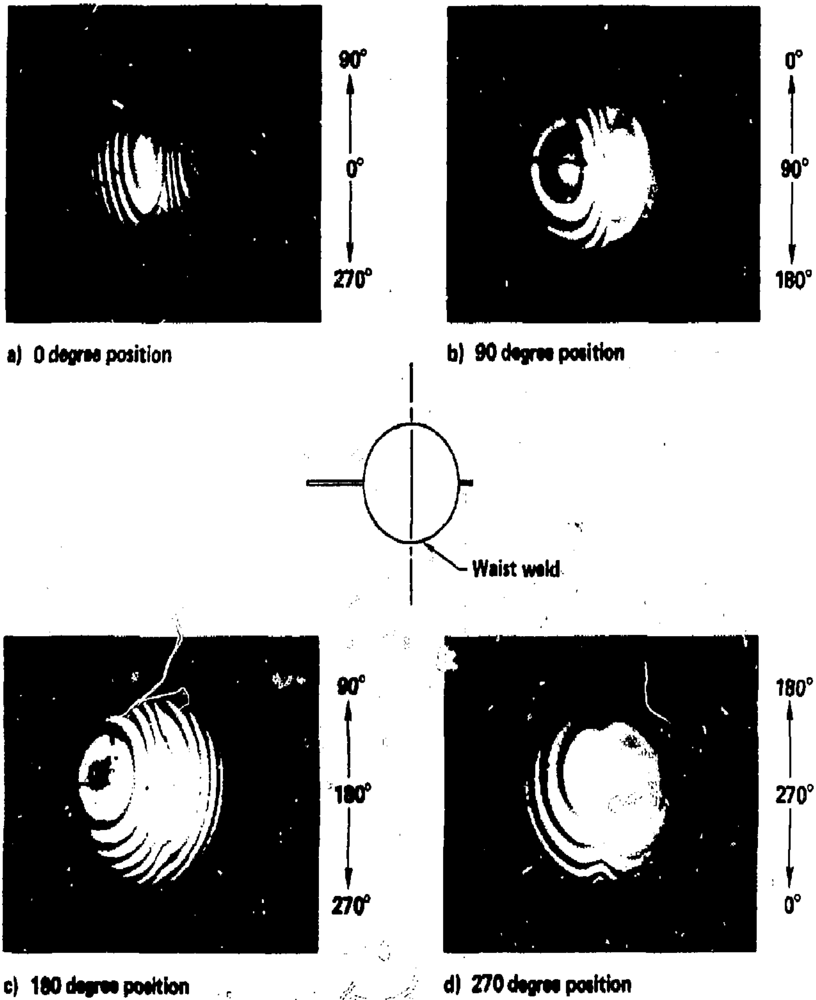


Fig. 3. Coincident viewing and illumination double-exposure holograms of vessel A for 0,90,180, and 270 degree positions on the waist weld. (Pressure differential 0.86 MPa) Nonuniform radial displacement is evident from the four views. At the 0 degree location lack of fusion results in a bending moment causing a non-uniform displacement across the weld.

0°

90°

270°

180°

Fig. 4. Parabolic mirror double exposure hologram, (Pressure differential-1.78 MPa) for vessel A. The fringe density and sharpness of the pointed fringe pattern at the weld indicate nonuniform radial displacement. The highest fringe density at 0 degrees corresponds with results from the coincident viewing and illumination hologram shown in Fig. 3a, (area of greatest lack of fusion).

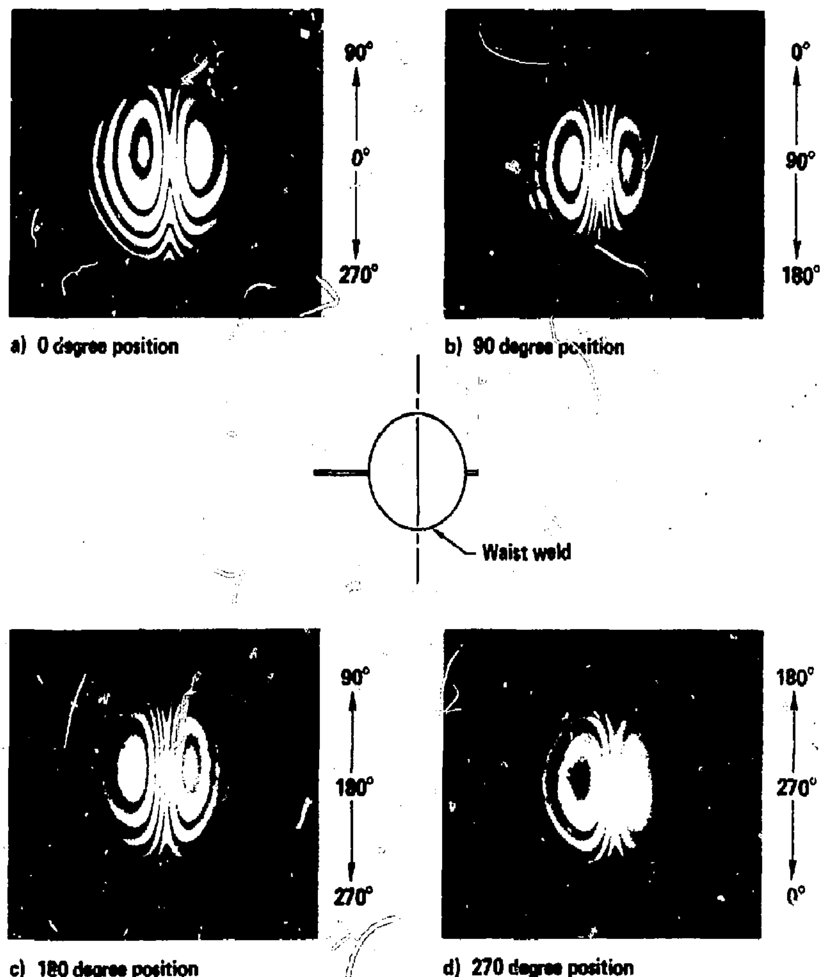
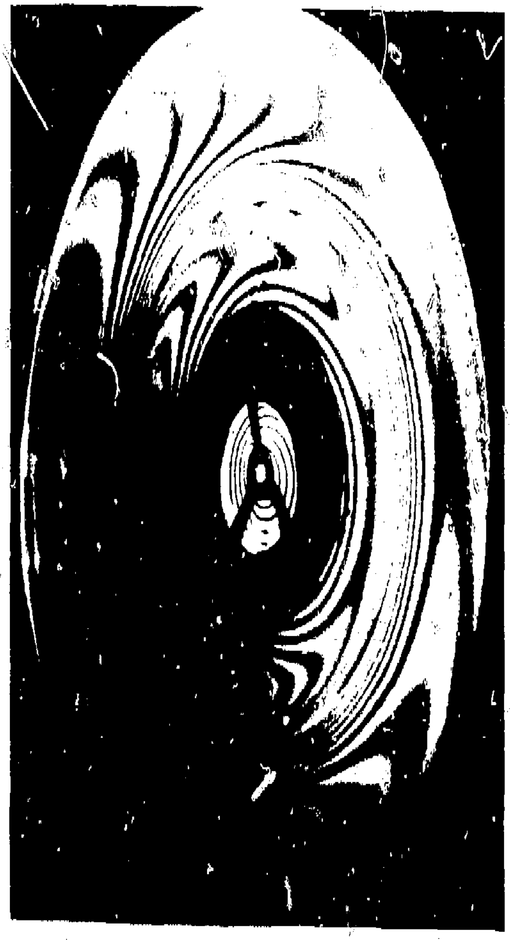


Fig. 5. Coincident viewing and illumination double exposure holograms of vessel B for 0,90,180, and 270 degree positions on the waist weld. (Pressure differential 0.86 MPa) These holograms show much less variation in the fringe pattern surrounding the weld area indicating lack of fusion around the entire waist.

0°

90°



270°

180°

Fig. 6. Parabolic mirror double exposure hologram, (pressure differential-1.78 MPa) for vessel B. This shows uniform fringe density around the weld and corresponds with the fringe information in the holograms shown in Fig. 5. The highest fringe density, located from 90 to 180 degrees, indicates the area of least fusion.

Fig. 7. Successive holograms from the real-time recording of vessel A. Pressure is increasing to the right (0-1.78 MPa). Residual straight-line fringes were present before pressurization began. Pointed fringes first appear at the weld area near the 0 degree location. This corresponds with the worst area of the weld recorded by the ultrasonic "C" scan shown in Fig. 9.

Fig. 8. Successive holograms of vessel B real-time recording. Pressure increases to the right. (0-1.78 MPa) The pointed fringes are seen to appear around the entire weld area at nearly the same time. The sharpest points are seen at 145° which corresponds with the worst area recorded by the ultrasonic "C" scan shown in Fig. 10.

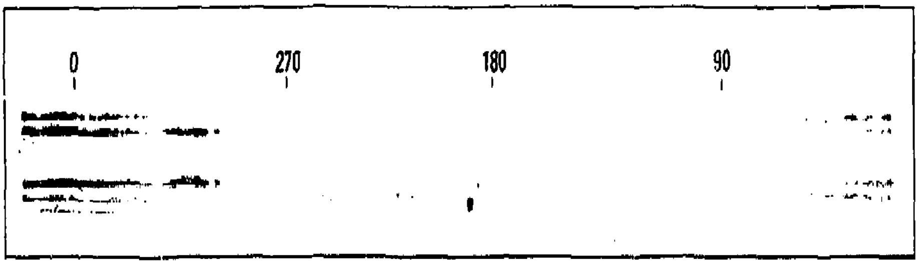


Fig. 9. Ultrasonic "C" scan of weld region of vessel A. A dark region indicates a flaw in the weld. Two passes are made with the ultrasonic transducer so that a mirror image is seen in the scan. The worst area extends from 300 to 45 degrees.

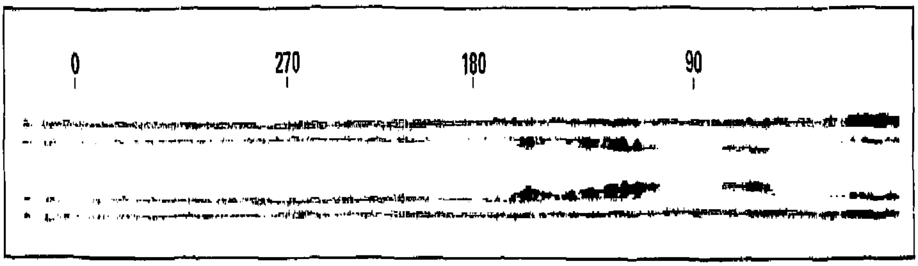


Fig. 10. Ultrasonic "C" scan of weld region of vessel B. The extent of the dark area indicates the entire weld is "bad". The worst area extends from 110 to 180 degrees.