HOLOGRAPHIC DIAGNOSTICS OF WELDED JOINTS OF STRUCTURES

L.M.Lobanov, V.A.Pivtorak*

The paper describes the method of a holographic interferometry for the determination of stress concentration in the zone of a possible fracture. The efficiency of the holographic method for the solution of different engineering problems is shown.

In modern branches of industry the thin-walled and thin-sheet structures, to which the requirements of high performance and reliability are specified, find the wide application. These structures are, usually, subjected to the conditions of a complex mechanical action and temperature gradients. The stress concentration occurring in the zone of defects of welds, causes, in some cases, the fracture of such structures.

The strength of weldments is, mainly, determined by the level of stresses occurring in the zone of their high concentration, as well as in the places of defects of welded joints. The different kinds of defects can cause the similar level of stresses depending upon their location and the conditions of the structure service.

In some cases it is rational to make the diagnostics of the performance of welded structures not by the size of defects, but taking into account the value of stress concentration, which is appeared due to cracks, lack of penetration, design peculiarities,etc.

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* E.O.Paton Electric Welding Institute, Kiev, Ukraine

At present the application of different methods, such as acoustic, tensometric, X-ray, optical and others, is known for the examination of structures. Each of these methods has advantages and drawbacks, however, none of these methods is versatile and does not satisfy all requirements specified to the methods and means of the examination.

Meanwhile, the engineering practice puts continuously forward new problems before the methods of examination. New methods permitting to obtain the more complete information about the object examined are necessary for their solution. The method of optical holographic is referred to these methods.

The E.O.Paton Electric Welding Institute has developed a new high-precision contactless holographic method of determination of a stress-strain state in the welded structures. The method permits to determine three components of a displacement vector of the points of object being studied. Here, the surface and near-surface layer of the component or structure member is examined. It is the state of this layer and acting stresses that determine in some cases the performance of the object. In the surface and near-surface layers, subjected to the mechanical or other kinds of treatments, not only the microroughness is appeared, but also their physico-mechanical state is changed, that is manifested in the change of structure, level of residual stresses and others. In the service conditions the surface and near-surface layers are subjected to small stresses from external loads due to not strict axial tension, compression of structure members and almost always bending and even torsion. It results, as a rule, in an appearance of fatigue cracks in these layers, thus leading to the failure of member or the whole structure. In this connection the necessity appears in the determination of the stress-strain state of surface and near-surface layers of products both during their manufacture and service.

The developed method was used for the examination of fields of residual stresses in the 01420 alloy welded tubular elements with an alternating rigidity. The tubular elements of 160 mm OD had the 3 mm thick wall in the zone of welding. The end regions (l =30 mm) of the tubular element had the 30 mm wall thickness. The welds in tubular elements N 1, 2, 3 were arranged at 8, 19 and 22 mm distances from the rigid edge. The studies were aimed at the examination of weld location effect (distance from the rigid edge) on the value of residual stresses.

The interference fringe patterns in the examined points of the tubular elements are shown in Fig.1-3.

The carried out analysis showed that the concentration of the interference fringes which characterizes the level of residual stresses, is continuously increases in the weld approaching the rigid edge. Here, the longitudinal tensile stresses reach the maximum value not in a weld (for the specimen with a minimum distance from the rigid edge - Fig.1), but in the region of fusion. Depending upon the distance from the rigid edge the stresses are varied from 50...200 MPa in the HAZ and from 135...180 MPa in the weld. Thus, the location of weld at the 8 mm distance from the rigid edge is most unfavourable, since it causes the high stress concentration in the weld zone. In designing of welded structures it is necessary to take into account that such a location of welds may cause the failure of elements, in particular, if they are subjected to the alternating loads.

The method of the holographic interferometry was also used for the study of the design strength of welded multilayer spherical high-pressure vessels.

The design of spherical vessels consists of two three-layer semi-spheres, being interwelded. The pressure was supplied inside the spherical shell. The geometric parameters of the high pressure vessels were as follows: ID/d/ = 123.5 mm; OD/D/ = 129.5 mm; wall thickness /t/ = 3 mm. The strength of high pressure spherical shells, which differ by the conditions of welding joints, the design of nozzle welding up and mechanical properties of materials, were studied.

The aim of examinations consisted in determination of defect location , determination of values of coefficients of stress concentration in the zone of defects, determination of spots of shell failure and values of critical pressure of failure.

Such defects influence the field of displacements, their presence forms some features (irregularities, fractures, regions of localization and so on) in the interference fringe pattern. The process of defect revealing is simplified when comparing the interference patterns, obtained in case of the object being examined and the defectless (reference) one.

Fig. 4 gives the interference fringe pattern formed in the spots of defects (N 2, 3, 4) of the three-layer spherical shell 1 (σ_b = 1450 MPa). The qualitative estimation of the zone of the defect location (Fig. 4a) testifies that the gradient of the interference fringes in the spot of defect N 2 is highest, and, consequently, this defect is the most hazardous in case of the vessel service. The predicted failure pressure for this defect was P_{pr} = 84.00 MPa.

In photo of spherical shell 1 after failure the crack propagating through the defect N 2 (Fig. 4,b) is distinctly expressed. The experimantal failure pressure in this case was P_f = 90.60 MPa.

Fig. 5a gives the interference fringe pattern formed in the zone of defect N 1 of the three-layer spherical shell 1. The predicted failure pressure in this case was P_{pr} = 84.4 MPa. Photo (Fig. 5,b) shows that the crack passed through the defect N 1.

The photo of failure of spherical shell 1 in the points of nozzle welding-up (Fig. 6) confirms the interference fringe pattern, formed in the mentioned spot (Fig. 6,a; P_{pr} = 84.00 MPa). It should be noted that the visual inspection of the structure did not allow to reveal defects in the zone of the nozzle welding-up, only the loading of the spherical shell with an inner pressure (2.50 MPa) gives the interference pattern in which the interface of the nozzle region and parent metal is clearly expressed.

Thus, for the given spherical shell 1 the most dangerous spots were distinguished among the all revealed defects (N 2, Fig. 4,a; N 1, Fig. 5,a; region of nozzle welding-up, Fig. 6,a). The predicting pressures (P_{pr}) of spherical structures in the spots of defects are very close by value, therefore, the failure tests showed that the structure failed in the spots of all three predicting stress concentrators. The numerical values P_{pr} were somewhat lower, as compared to the actual P_f - by 50%.

The similar experiments and tests were carried out on high pressure spherical shells 2 (σ_b = 1250 MPa), 3(σ_b = 1250 MPa), 4 (σ_b= 1100 MPa).

It should be noted that in study of spherical shells 3 and 4, having different strength characteristics of the material the similar fracture pressure was set. It was explained by the fact that two defects with maximum coefficients of stress concentration, close by values, were revealed in the stronger structure 3 that considerably reduced the value of the fracture pressure.

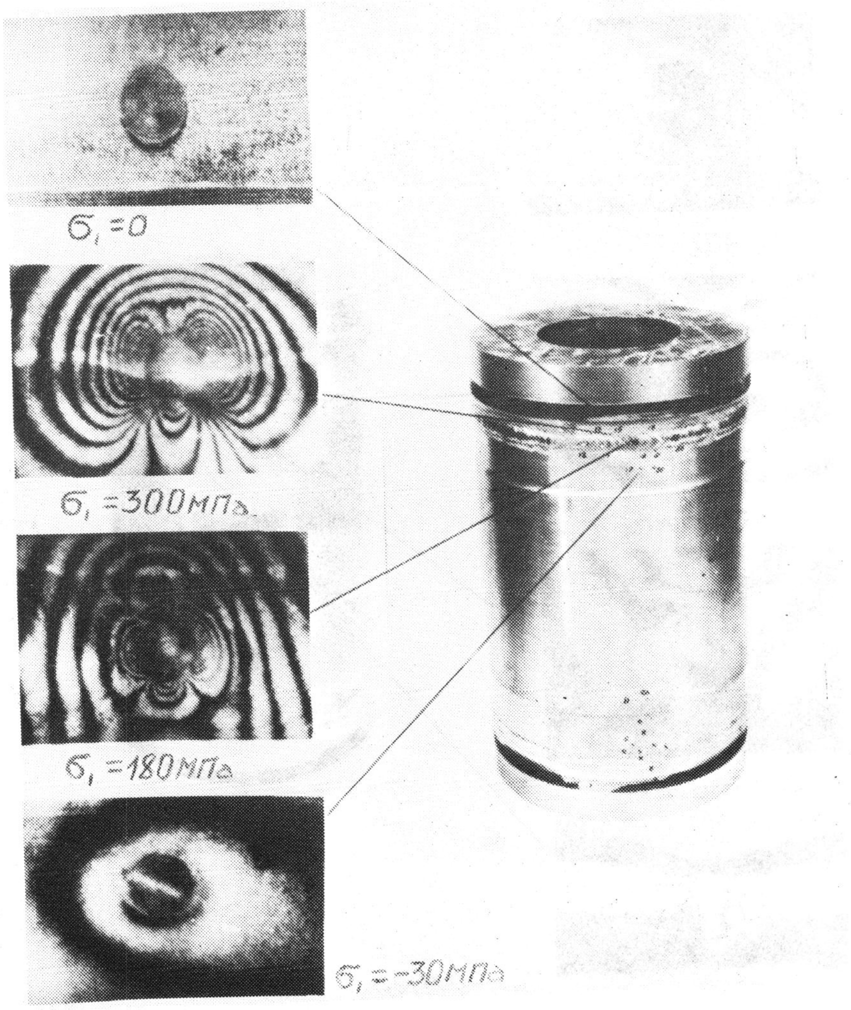

Figure 1 Interference fringe pattern and values of residual stresses in the welded tubular element No. 1

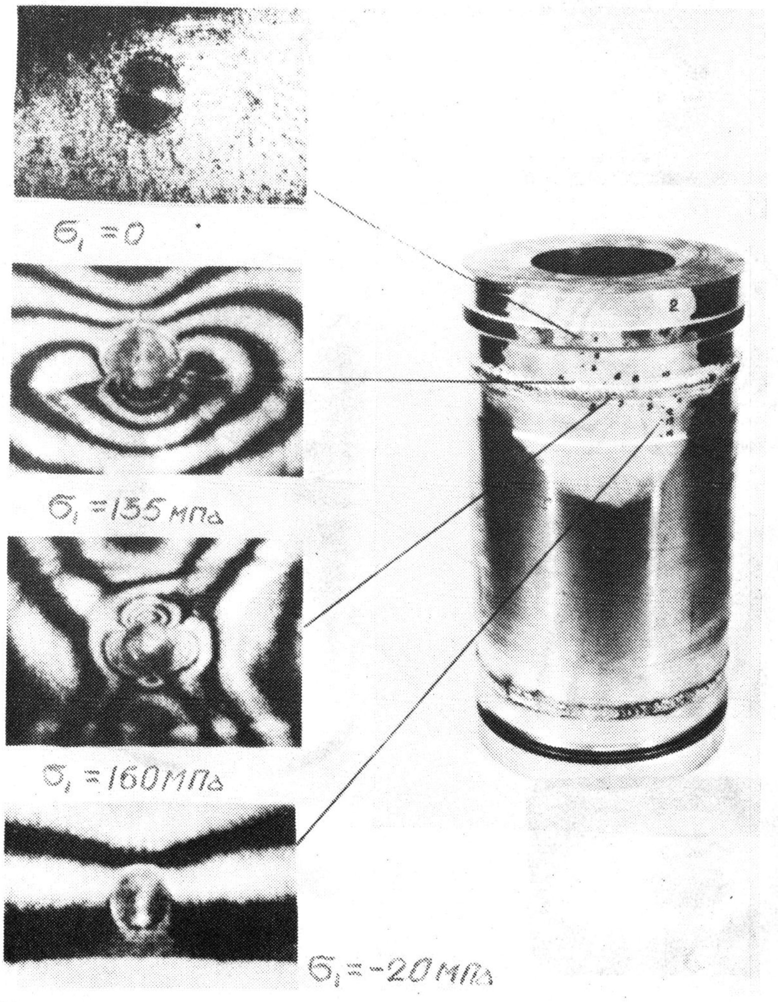

Figure 2 Interference fringe pattern and values of residual stresses in the welded tubular element No. 2

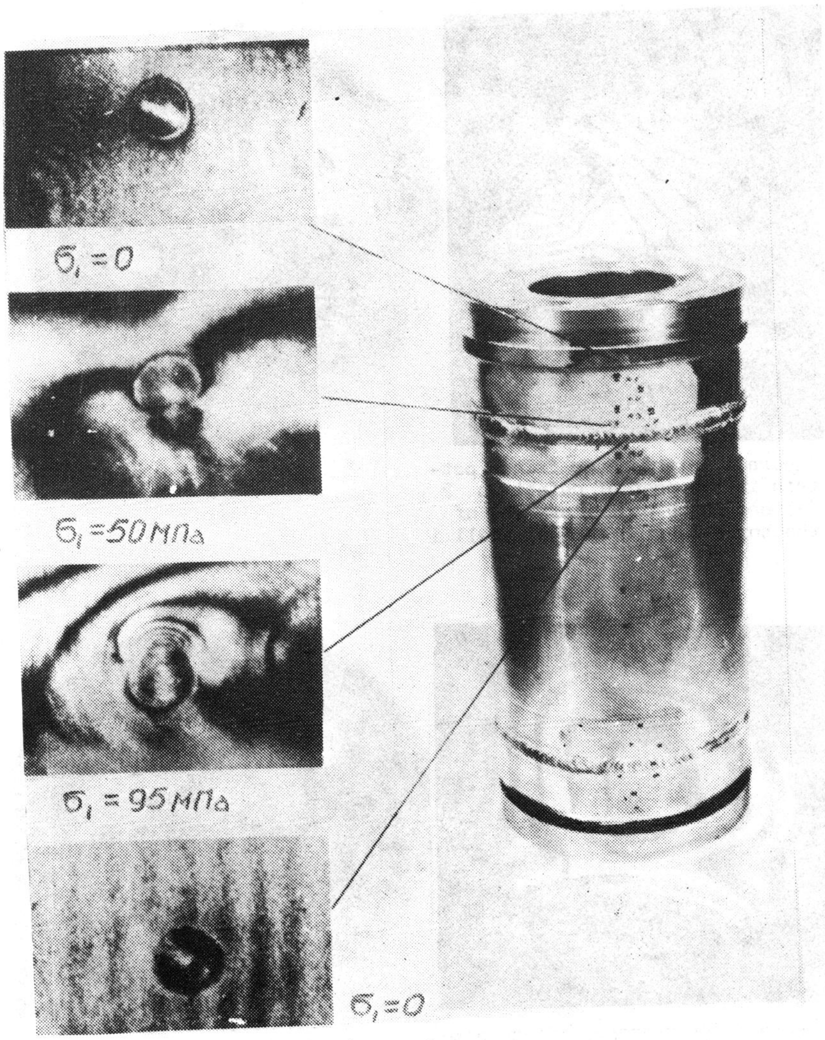

Figure 3 Interference fringe pattern and values of residual stresses in the welded tubular element No. 3

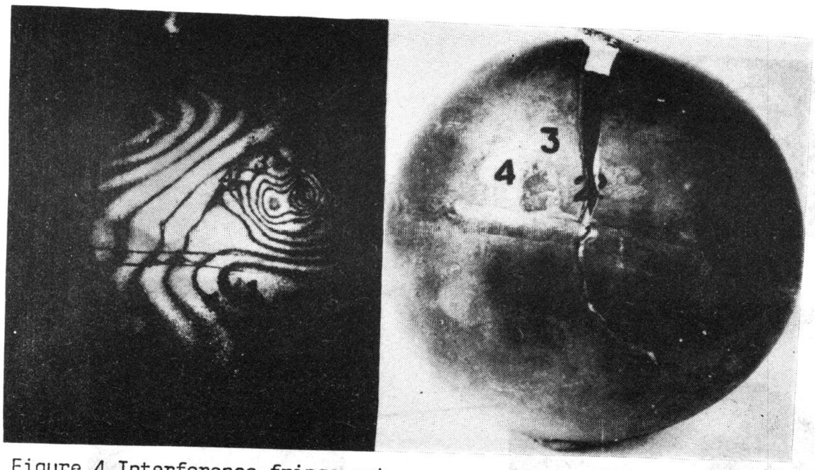

Figure 4 Interference fringe pattern in the spot of defect No. 2 (a) and photo of failure (b) of the three-layer spherical shell 1

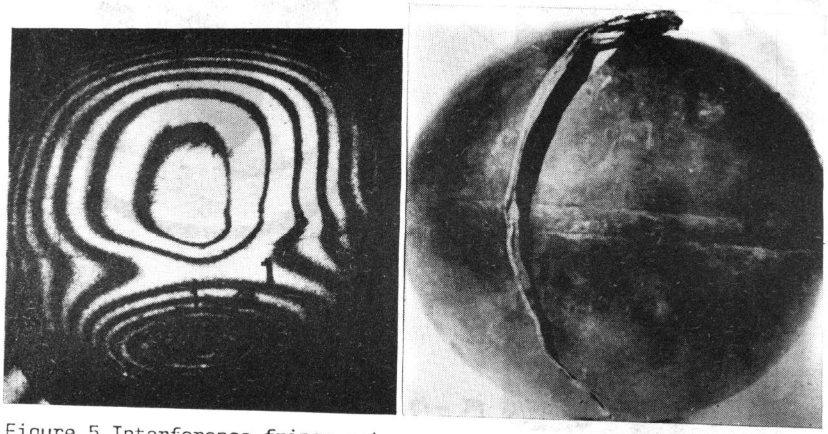

Figure 5 Interference fringe pattern in the spot of defect No. 1 (a) and photo of failure (b) of the three-layer spherical shell 1

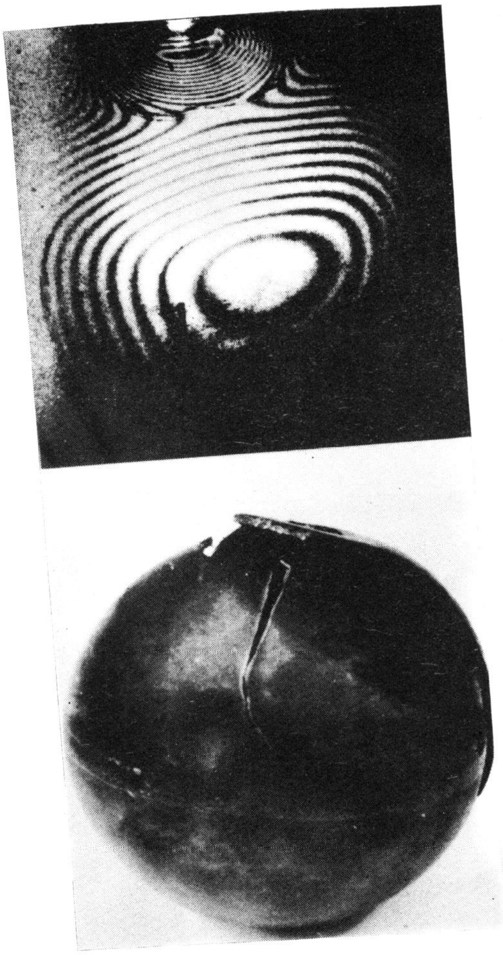

Figure 6 Interference fringe pattern, in the spot of nozzle welding-up (a) and (b) is the photo of failure of the three-layer spherical shell 1