HOLOGRAPHIC DIAGNOSTICS OF WELDED JOINTS AND STRUCTURES

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ABSTRACT

The results of holographic non-destructive quality control of welded tubular elements of stainless steel and titanium, as well as pipes of non-metallic materials are presented. The data are given on the quality control of protective strengthening coatings of turbine blades. The results of the holographic examination of residual stresses in gas turbine engine components made by EBW are discussed.

KEY WORDS

Holographic interferometry, quality control,residual stresses, welded structure elements.

The long service life, reliability of machines and structures can be provided at the conditions of a comprehensive study of their strength. The presence of local defects in material and microcracks in large components or the presence of high residual stresses and dynamic mode of loading can lead to a premature brittle fracture even at a plastic state of the material of steel components even at a room temperature. Analysis of strength characteristics of structure members is an integrated part of investigations of their quality and stress-strain states specified by the technological processes of their manufacture and service conditions.

One of the effective experimental methods of study of stress-strain states and quality control of welded structures is the method of holographic interferometry permitting to contactlessly reveal the surface or inner defects and to simultaneously measure three components of vector of displacements. At the E.O.Paton Electric Welding Institute of the Academy of Sciences of Ukraine the method of the holographic interferometry is widely used for the quality control and determination of residual stresses in elements and members of different structures of metallic and non-metallic materials.

The holographic interferometry can provide the direct quality pattern of distribution of deformations along the whole object surface applying the definite forces to it, not making the measurements of the interferogram being formed. Even without the further analysis this pattern gives the useful information for the control purposes by detecting different kinds of defects.

The reliability of revealing defects on the basis of a quality analysis of interferograms is determined, mainly, by a proper consideration of the two following factors. Firstly, by a selection of an optimum kind of object loading, that is, by a creation of such stressed state which leads for a given type of defects to the largest differences in distribution of displacements and deformations along the surface of object in defective and defectless regions. Secondly, by using the holographic interferometer sensitive to that component of the vector of displacement on whose distribution the presence of defect is affected to the highest extent at a preset loading.

The experience of using the method of holographic interferometry for the quality control of different-purpose welded structures displayed its high efficiency. Here, the different designs of holographic interferometers having the adjustable sensitivity are used.

Thus, for instance, two-beam systems of recording holograms were used in quality control of welded thin-walled small-diameter tubular elements made of stainless steel and titanium. The specimens of stainless steel tubular elements of 10 and 25 mm dia. The tubular specimens were loaded with the help of mechanical bending loading in the weld zone. The interference fringe pattern of 10 mm dia. tubular specimen with a defect of a "lack of penetration" type is shown in Fig.1a. The defects of such type are rather dangerous since they can cause the structure fracture. They are revealed at small loadings. In case of a quality weld the reference fringe pattern has an appearance shown in Fig.1b.

The further increase of applied load permits to visualize zones with a drastic change of mechanical properties in the element studied, that is displayed in a local concentration of fringes in weld length. In this case, the curve of hardness change in weld and HAZ has an appearance shown in Fig.2, testifying the remarkable change in weld metal properties. By changing the level of loading tubular specimens being studied, it is possible to reveal different types of defects including the zones of weakening and quenching. The interference fringe pattern of weld region with defect of "burning- through" type (10mm dia. specimen) is shown in Fig.1c. In the whole weld length the local concentration of interference fringes, caused by a remarkable heterogeneity of mechanical properties of weld, is observed at the another level of loading.

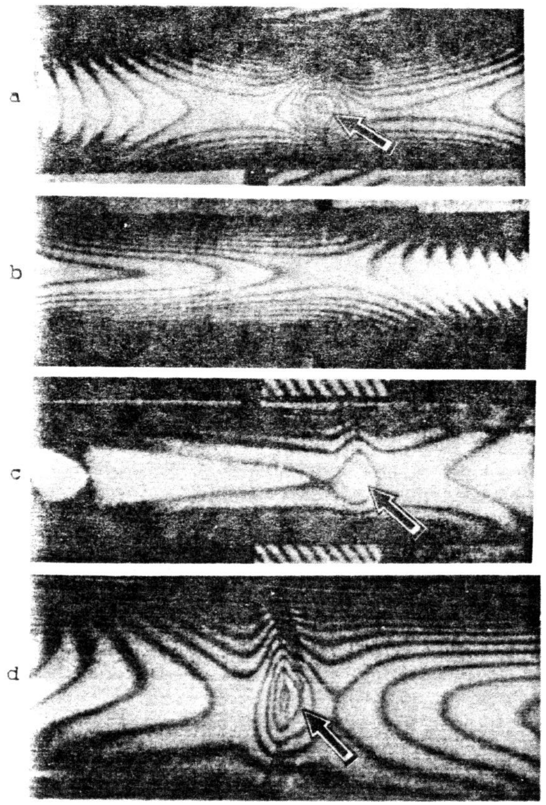


Fig.1. Interference fringe pattern in weld of stainless steel tubular elements.
a - fringe pattern in the zone of defect of "lack of penetration" type;
b - reference fringe pattern;
c - fringe pattern in the zone of defect of "burning-through" type;
d - fringe pattern in welded tubular 25 mm dia. specimen

The study of 25 mm dia. tubular element showed the local concentration of interference fringes in weld along the whole length,that is probably due to the weld metal weakening The typical fringe pattern in weld is shown in Fig. 1d. The analysis of the obtained results has shown that the holographic interferometry can record different defects in weld in stainless steel specimens; here, the feasibility of revealing of regions with a remarkable change of mechanical properties being opened.

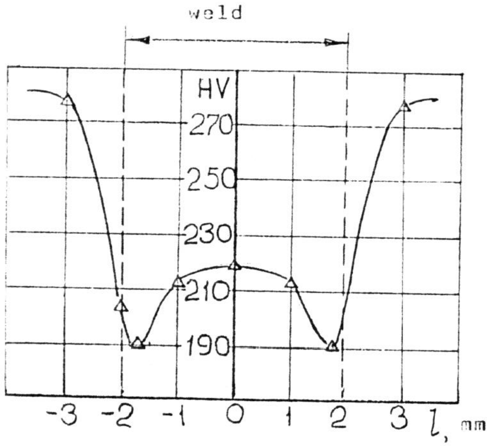


Fig.2. Curve of hardness change in welded tubular specimen of stainless steel.

The examination of welds in titanium tubular elements showed that in 10 mm dia. specimens a local concentration of fringes was revealed at one of the regions in weld length at the line of fusion (Fig.3a).The rest part of weld was quality (Fig.3b).

The non-destructive . testing of quality of high pressure turbine vanes, having 40 um thick ceramic coating over the metallic one, was made by using the holographic interferometry. The experiments were carried out at the stand of holographic equipment, the two-beam optical system was used for the hologram recording.

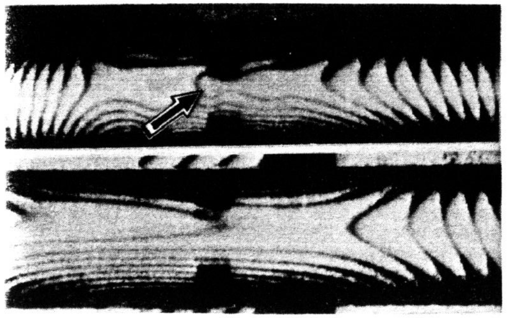


Fig. 3. Interference fringe pattern in weld of titanium tubular elements

During investigations both thermal and mechanical loading was used for visualizing defective regions. Fig.4 shows the interference fringe pattern of vanes at mechanical loading. The regions with bends and abrupt change of fringe curvature which characterized the non-quality regions in the coatings of vanes being investigated were visually detected. Such defects can lead to the protective coating failure.

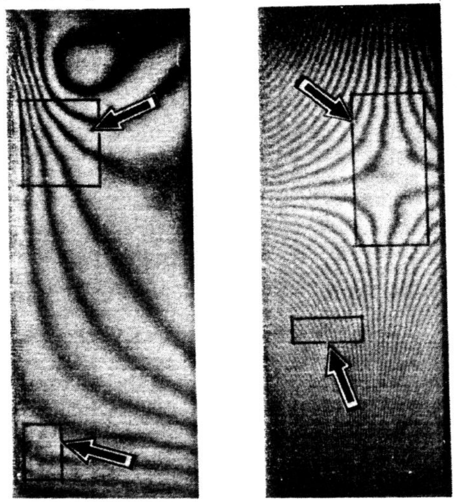
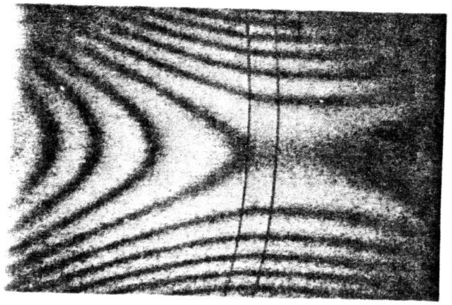


Fig.4. Interference fringe patterns characterizing the quality of protective coatings of high pressure turbine vanes.

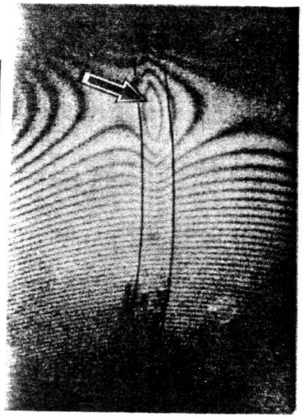
At present the welding production encounters an urgent problem of providing high performance of welded polymeric pipelines. Till now there is no a sufficiently reliable non-destructive testing of polymeric pipeline welded joints in the world. The existing NDT methods can reveal only coarse defects, while the load-carrying capacity of plastics and their welded joints is mainly determined by so-called defects of a structure heterogeneity.

Different microscopic defects in welded joints of plastics (inclusions, pores, cracks, non-fusions, etc.) considerably influence the joint strength. It should be noted that the control of defects with a small opening, of "lack of fusion" type,with a help of X-ray and ultrasonic methods is difficult.

In investigation of welded butt joints of 110 mm dia. 10 mm wall thick polyethylene low-pressure pipes the mechanical loading of weld zone by bending was used. The interference fringe pattern in tubular element distinctly visualizes the defect in the weld zone (Fig.5b). The unquality weld is characterized by interference pattern in which jumps and bends of fringes are observed. This is well seen in comparing with fringe patterns occurring in the zone of quality weld (Fig.5a). The application of the polyethylene feature, its intensive



a



b

Fig.5. Interference fringe pattern
in quality control of welded
polyethylene pipes.
a - reference pattern;
b - weld with defects.

creep at small loading, is promising for quality control of welded pipes.The carried out experiments showed that the heterogeneity in a field of displacements is observed in the zone of inner defects during study of creep in weld regions in a real time (Fig.6), this characterizing the presence of defects. The study of creep process mode also permits to reveal regions of weld and HAZ with different mechanical properties. The feasibility of creep process visualization in weld region in real time opens up new opportunities for quality control of pipelines in field conditions. The technological process of welded structure fabrication inevitably leads to the formation of fields of residual stresses.The level of stress state influences the strength of structure elements,in the zone of a possible concentrator,in particular.Therefore, the problem of analysis of residual stresses in welded structures remains still actual.

The residual stresses in the welded stage of the titanium alloy gas turbine engine made by electron-beam welding were determined with the help of the developed holographic procedure. Fig.7 shows the general view of the gas turbine engine component, interference fringe patterns characterizing the level and value of residual stresses in the examined spots of the structure. The stress concentration in the zone of weld often leads to the welded structure failure.

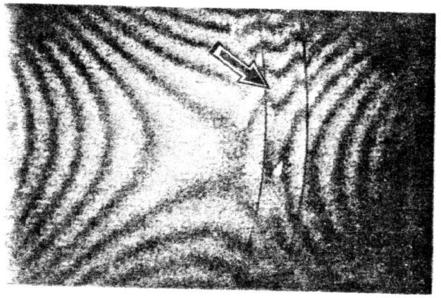


Fig. 6. Interference fringe patterns
in creep of weld with defect

In spite of a complicated geometry of the structure being examined the holographic method permitted to determine the value of residual stresses in the weld zone.

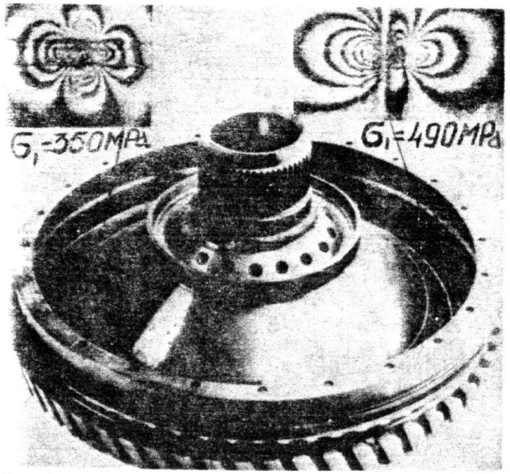


Fig. 7. Interference fringe pattern in the gas turbine engine component being electron beam welded.

The carried out experiments showed that the holographic method is an effective means of measuring residual stresses and diagnostics of quality of welded joints and structure elements of complicated shape, made of metallic and non-metallic materials.