STUDY OF DEFORMATIONSOF MATERIAL UNDER CYCLIC STRESSESUSING SPECKLE HOLOGRAPHY

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Abstract - The paper presents the study of deformations of materialespecially thestress concentrated area (fracture zone) causedby cyclic stresses by usingthe speckle interferometry. As a result, the physical structureof the materialinits fracture zonecan be analyzed more precisely.

Keywords - Speckle Interferometry, Stress Concentration, Material Fatigue, Cyclic Tests.

I. INTRODUCTION

Many machine parts and structural elements during operation experience cyclically varying stresses over time.An example of a cyclically varying stress is shown in figure 1.

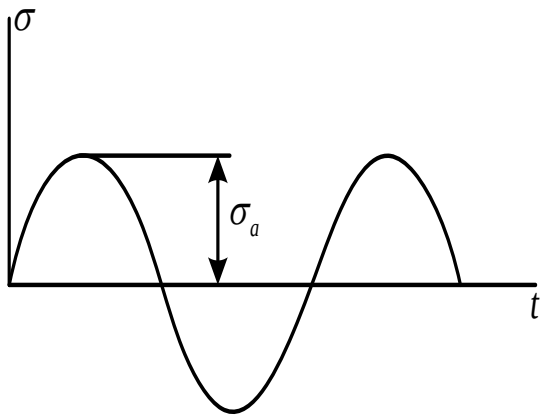


Fig.1.Example of a cyclically varying stress

In this experiment, it is shown that the deformations of the material can be occurred after a certain number of cycles of variable stresses, even a relatively small value within its elasticity. The number of cycles until fracture depends on the magnitude σ_a and changes in very wide limits.

At high stresses, deformations can be occurred while the cyclic stresses are close enough to σ_t 5-10 cycles (for example low cycle fatigue). At low stresses, the part can withstand $10^6 - 10^9$ cycles or, depending on the material and operating conditions, it is able to work indefinitely.

II. DETAIL EXPERIMENT

2.1The basic method of speckle holography

The practical implementation of the method is described in details in the following. The optical method of registration of speckle holograms is shown in figure 2.

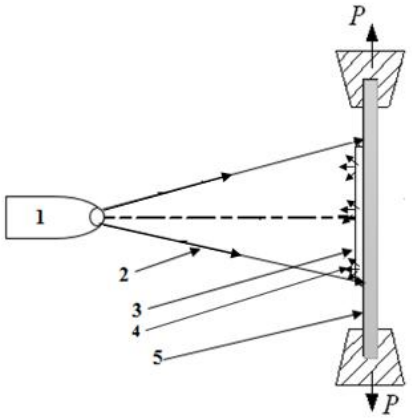
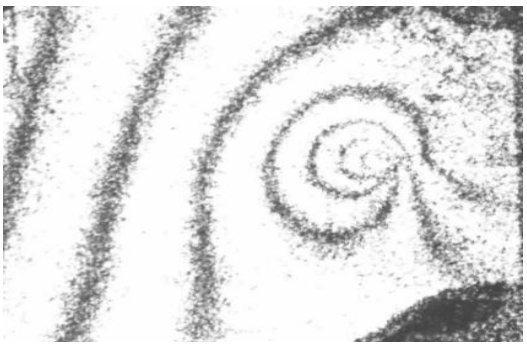


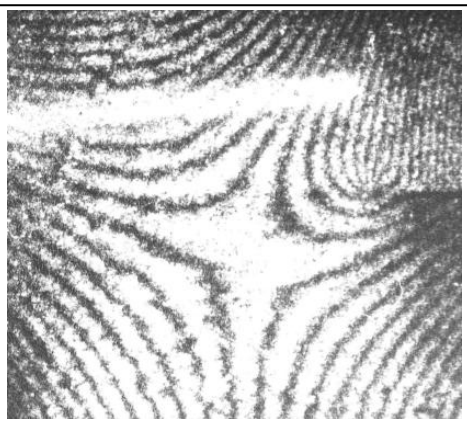
Fig.2. The Optical Method of Registration of Speckle Holograms in the Colliding beams on the Specimen in the Testing Machine

1)semiconductor laser, 2) laser beam, 3)speck-hologram , 4)diffraction wave of the object, 5) the object

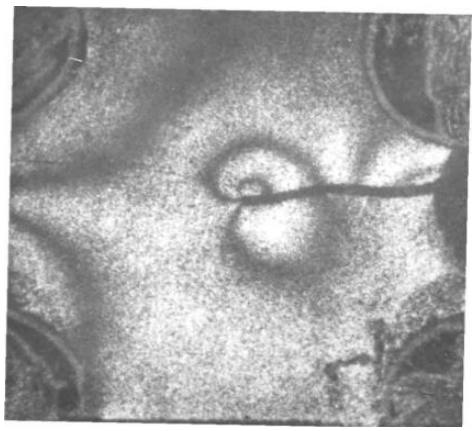
In this method, speckles (granularity) of a diffusely reflecting object, which is illuminated by coherent light, are used. The speckles have a diffraction nature and are occurred because of the diffuse component of the object illuminated by coherent radiation, in which rays are scattered on the rough surface of the object under study.
An example of the obtained interferograms of spatial displacements on the components u,v,w with a crack is shown in figure 3.[1]



w



V



U

Fig.3.Interferograms of spatial displacements on the components u,v,w

Another example of holographic interferograms, in which a special sample is used for the determination of stress intensity factor (SIF)and a volume crack, is shown in figure 4. In this interferogram, the kinetics of the development of a volume internal crack is presented.

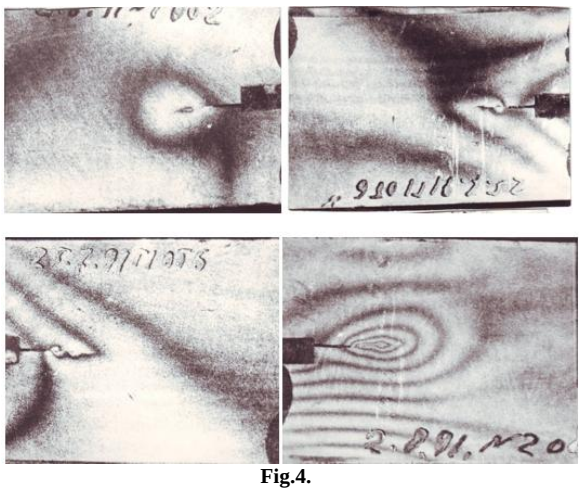


Fig.4.

Experimental methods of analysis can be performed for various structural elements and machine parts on the basis of holographic methods. Moreover, the computational methods of analysis considering the physical experimental data, can be performed using a three-dimensional spatial formulation, including fracture mechanics, and the finite element method (FEM).

III. RESULTS AND DISCUSSION

3.1. The results of the study of the material

The results of the study of fatigue characteristics of the material can be considered to be the stress concentration zone near the hole.Fatigue characteristics of materials are usually obtained on special samples during cyclic tests. In this experiment, the analysis is performed using the stress concentration zone near the cutouts of aviation materials [2-3].

In the Figure 5, an interferogram in the zone of a special cutout is presented. The characteristic thinning (fossa) in the stress concentration zone is observed in the band pattern.



Fig.5.

When flat sample with the cut is analyzed, the interferogram of the stress concentration zone can be found in the formation of the thinning of the material. A sample of material, D-16 with the parameters of plate width 20 mm, thickness 3 mm and hole diameter 3 mm, is used to test.Cyclic loading are shown in figure 6.The residual deformations at the component of w with the price of the strip, 0.3 μm at the distance from the hole 0.4 mm after cyclic loading are shown in figure 7.

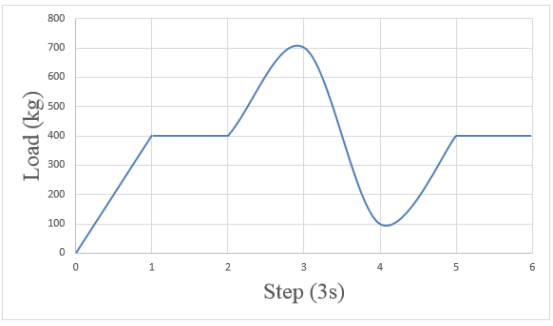


Fig. 6.Program for cyclic loading in the machine

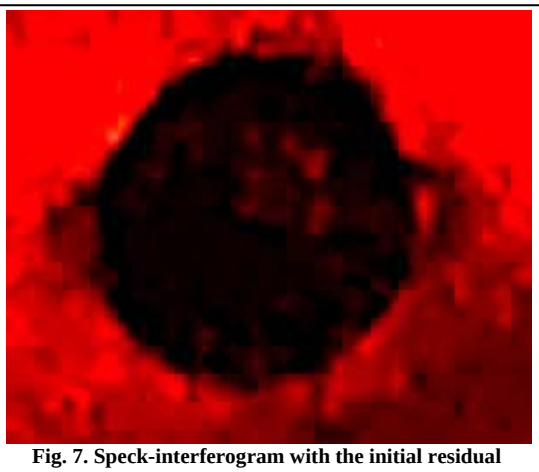


Fig. 7. Speck-interferogram with the initial residual deformation

As an another experiment, a special sample of material D-16 with the parameters including thickness 2 mm, width 60 mm, cut width 6 mm and hole diameter 3.5 mm is tested. The cyclic loading and the resulted interferogramafter the first cycle of fatigue test are presented in figure 8 and9 respectively.

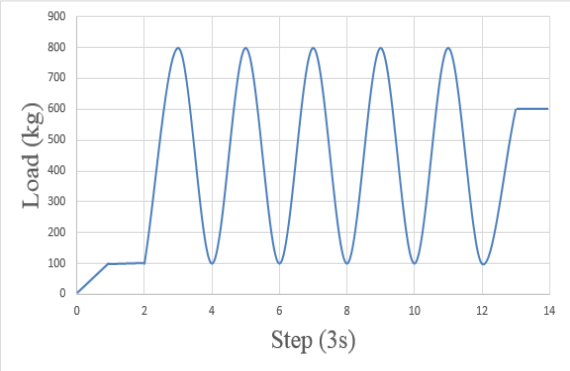


Fig. 8.Program for cyclic loading in the machine

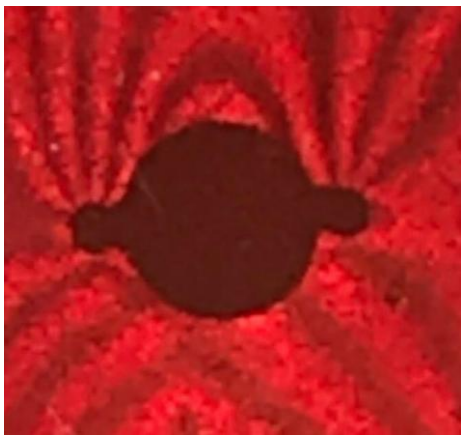


Fig. 9.Speck-interferogram after the firstcycle loading

According to the interferogram, fatigue damage is observed in the stress concentration zone by a value ofthe strip 0.3 μm at the distance of the first strip.
The interferogram after 50 test cycles is shown in Figure 10.The expansion of the zone of fatigue damage is observed as 3 stripes.



Fig. 10.Speck-interferogram after 50 cycles loading

The results of fatigue tests of a volumetric sample are shown in the following.

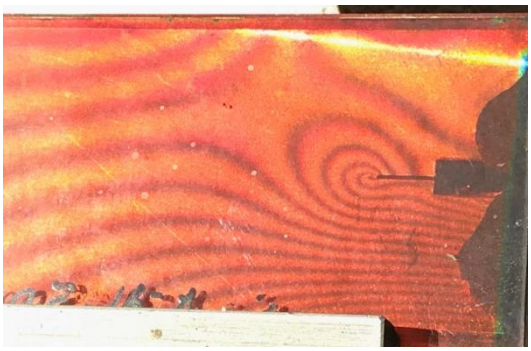


Fig. 11. Interferogram before cyclic loading

A special thick sample, in which a volume crack cannot be occurred on the surface, is used to determine the stress intensity factor. The interferogram after the formation of an internal volume crack is presented in figure 12.



Fig. 12.Interferogram after cyclic loading

On this interferogram, a subsurface volumetric crack, which cannot be seen on the surface, can be observed.

CONCLUSIONS

The deformation of material under cyclic stresses was studied using the speckle holography and the major conclusions are as follow:

1. More accurate physical analysis of the material in its fracture zone can be performed. As a result,

the stress intensity factor (SIF) can be calculated by the methods of linear fracture mechanics so that the complexity of the real conditions of the material in the crack zone, can be considered more exactly.

2. The rate of crack propagation in various materials can be estimated more reliably.
3. The parameters of survivability and residual durability of the material can also be determined more reliably.

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