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THERMAL DEFORMATION WAVES IN HETEROGENEOUS MATERIALS

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Abstract. In the paper, a stress-strain detection method is used by correlation point interferometry, in which the resolution of the recording surface changes has been significantly (ten times) improved. This result was obtained by applying a different image-processing algorithm, which allows the recording of 3D surface changes in on-line mode. The deformation wave that occurs during heating propagates through the entire sample and interacts with the interfaces. The inhomogeneity and residual deformations of a material lead to a distortion of the front. The speckle electron interferometry (ESI) method allows the recording of this thermal deformation wave front and the estimation of the stress state of the studied material.

Keywords: *heterogeneous materials, stress strain, thermal deformation wave, speckle electron interferometry (ESI).*

Introduction

In earlier works [6-8], a method for studying the stress-strain state using correlation speckle interferometry was proposed. Recently, this method has been significantly improved by us, namely, the resolution of recording surface changes (about 10 nm) has been increased tenfold and the possibility of observing 3D surface changes in on-line mode has been implemented. Due to the use of a different image processing algorithm, this method should be called the method of electronic speckle interferometry (ESI) since here the measurement of movements on the surface is due to the measurement of the intensity of speckles, and not due to their correlation analysis as it was before [9]. The increase in the destructive ability of the ESI method allows us to reveal a number of new features of the deformation of stress-strain materials at a smaller scale level.

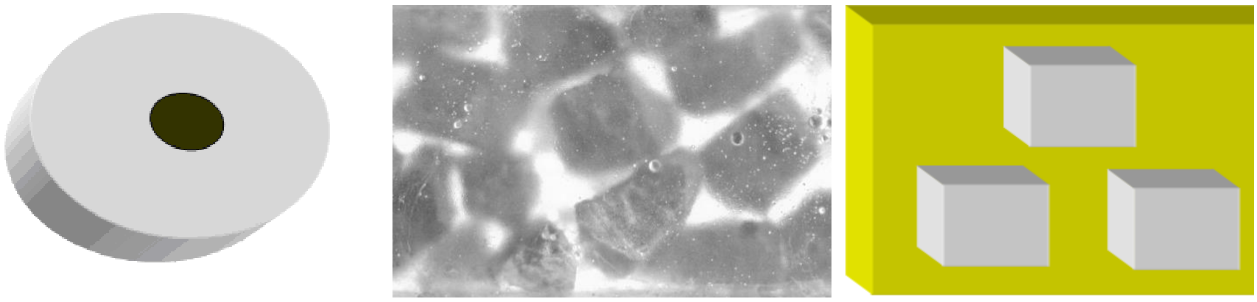
1. Hypothesis

In works [1-5] it was assumed that when heterogeneous or defective materials are heated, inhomogeneous deformation occurs due to the distribution of areas with different coefficients of linear thermal expansion (CLTE). According to local inhomogeneity's of deformation during heating, structural heterogeneity in the material can be detected. In principle, this assumption is valid for a relatively high temperature and the stationary process. However, according to new data, the presence of areas with positive and negative CTE with a small temperature increment (ΔT≈1^0C) requires a non-trivial explanation. The presence of deformation at the edges of the sample, which are not heated under small local temperature perturbations, requires an explanation.

In this paper, it is hypothesized that a deformation wave arises during heating, which is ahead of the temperature increase and propagates through the entire sample. The result of the interaction of a deformation wave with interfaces, inhomogeneity's, and residual deformations of a material leads to a distortion of its front. The ESI method makes it possible to register this front of a thermal deformation wave and estimate the stress-strain state of the material under study.

2. The methodology of the experiment

Samples of cement and epoxy resin-coated steel cylinders of rice were investigated. 1a, epoxy poured on clay expanded clay Figure 1b, epoxy poured on epoxy resin cubes Figure



a) b) c)

Figure 1. The investigated samples: a - steel cylinders filled in with cement and epoxy resin; b - clay filled with epoxy resin; c - epoxy poured dices of the eraser.

1b, marble aggregate poured with concrete.
Sample sizes 50 × 50 × 10 mm.

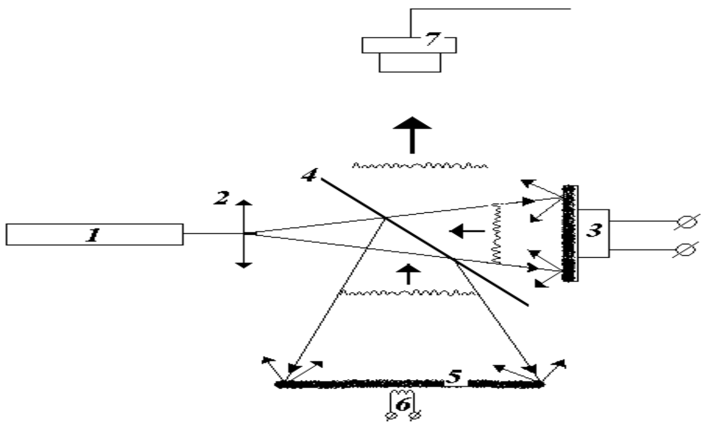


Figure 2. Scheme of the speckle interferometer.
1 - Helium neon laser, 2 - beam expander, 3 - diffuse scatterer mounted on piezoceramics, 4 - translucent mirror, 5 - sample, 6 - heater (tungsten helix 10 × 5 mm), 7 - camera.

The studies were conducted using a speckle interferometer, the circuit of which is shown in Figure 2.

Samples 5 in the center were heated by a heater 6 with a power of 2W until the surface temperature changed by 50°C. The temperature was controlled by a thermocouple with an accuracy of 0.5°C. With an interval of 5s, a change in the strain field of Figure 3 was recorded.

3. Discussion about the results of the experiment

The argument of the existence of a thermal deformation wave is the fact that the deformation of the surface of a bulk sample (thickness about 10 mm) begins literally from the first seconds after connecting the heater, when no change in temperature on the surface is observed. This can be explained by the fact that the expansion of a small volume that is in contact with a heater, caused by heating, is transmitted to the entire sample ahead of the heat wave up to its borders. The intensity of the transmitted strain essentially depends on the structural features and the stress state of the material under study. In fig. Figure 4 shows the deformation profile of clay filled with epoxy resin (Figure 1b).

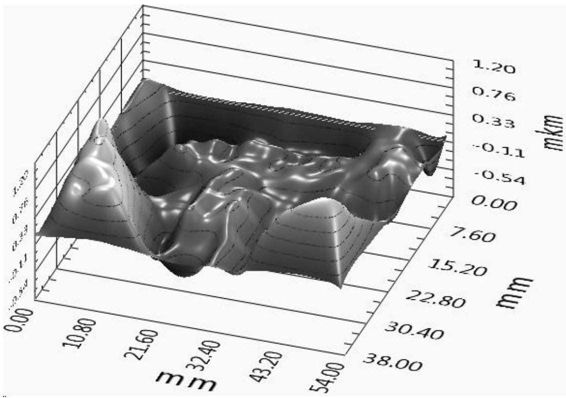


Figure 3. Deformation of a composite of erase cubes filled with epoxy resin (Fig. 1c) when heated in the center at 50°C.

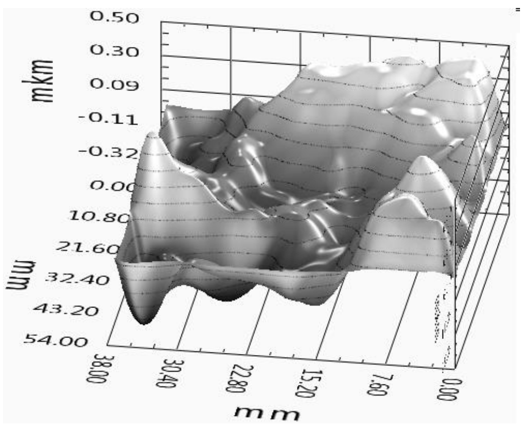
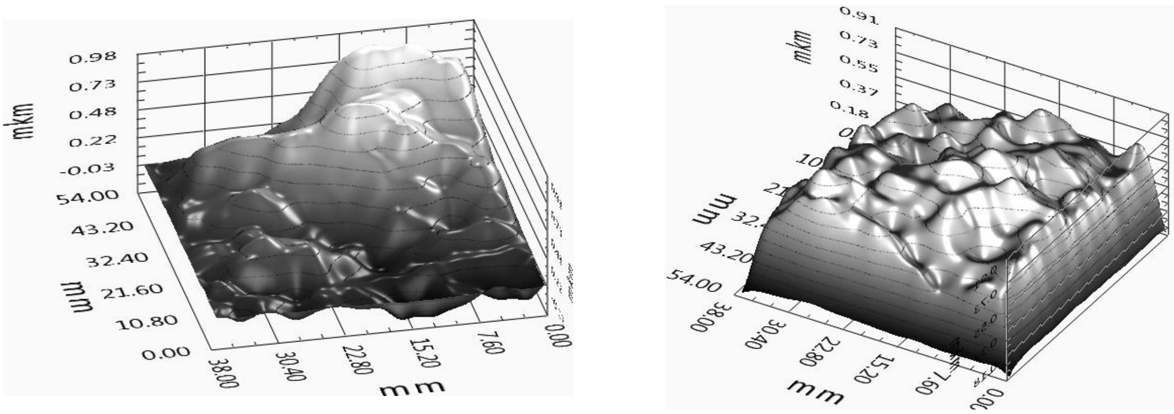


Figure 4. Deformation profile of epoxy poured clay.

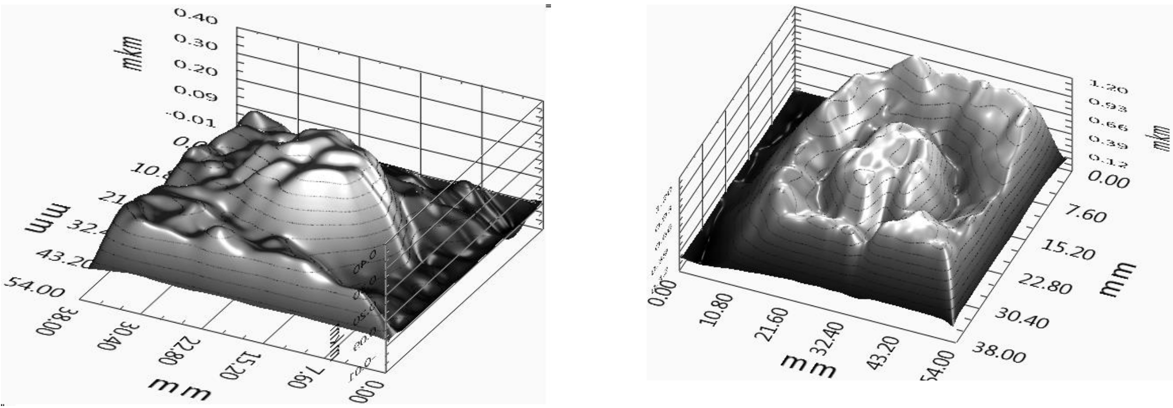
It is obvious that the deformation profile of the sample (Figure 4) characterizes its structural inhomogeneity. An interesting fact is that the sample has alternating deformations that are most intense at the edges where the temperature has not changed much. The most interesting is the case of deformation of a concrete sample with small marble chips (Figure 5).



a) *b)*

Figure 5. Profiles of deformation of a concrete sample with small marble chips: a - initial sample; b - the same sample subjected to shock loads.

Comparing the concrete samples before the shock load and after (Figure 5a, Figure 5b), one can notice that under the same conditions, the deformation of the latter occurs more evenly. This is due to the fact that shock loads stimulated the formation of microcracks and the relaxation of internal residual deformations (stresses). The conduct of a turn well demonstrated in Figure 6.



a) *b)*

Figure 6. Deformation profile of the composite filled with a - cement, b - epoxy resin of a metal cylinder (Figure 1a).

In figure 6a, the absence of matrix material in the right part is clearly visible. This indicates that in this part there is no adhesion between the metal and cement, and, accordingly, the general line of normal deformation is interrupted. A different picture is observed in figure 6b, where with good adhesion of metal with epoxy resin, but because of the differences in CLTE, the matrix material is squeezed out. In figure 3 shows the opposite pattern, when the matrix (epoxy resin), on the contrary, squeezes out less hard inclusions (eraser).

4. Conclusion

The use of the ESI method in the qualitative analysis of the stress-strain state of heterogeneous structures allows us to confidently turn to real materials that are beyond the limits of the applicability of the photoelasticity method. The question of quantitative analysis remains open. As shown in this paper, a series of cross-effects occur on a small scale level that require rethinking.

Referances

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