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# INVESTIGATION OF INELASTIC PROBLEMS BY REPRODUCING THE DEFORMATION HISTORY

`![Fig. 1](figure)`

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Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

## Abstract

## Full Text

## THEORY OF ELASTICITY

**A. Ya. ALEKSANDROV, M. Kh. AKHMETZYANOV**

# INVESTIGATION OF INELASTIC PROBLEMS BY REPRODUCING THE DEFORMATION HISTORY

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In experimental investigations of inelastic problems, the transition from directly measured quantities to stresses is carried out on the basis of the hypotheses and equations of theories of inelastic deformation, which are far less universal and exact than the corresponding relations for the elastic range. Below a method is set forth for the experimental determination of stresses in inelastic bodies, free from the necessity of using specific relations between stresses and strains. The method is intended for determining stresses on the surface of nonuniformly deforming bodies subjected to complex loading at small and large deformations. The method is based on the assumption that the loading process of an infinitesimally small element is uniquely determined by the process of its deformation and can be reproduced on uniformly deforming specimens of finite dimensions (the hypothesis of macroscopic definability).

**Fig. 1**

During the loading of a body, the history of deformation is recorded, for example by means of the photoelastic-coating method (^1) (i.e., the process of change of the components of the strain tensor) at points of the free surfaces of the body. This deformation process for an individual point of the body is reproduced, with the strain rates observed, on a homogeneously deforming thin–

**Fig. 2**

**Fig. 3**

walled tube made of the same material, subjected to the combined action of tension, torsion, and internal pressure, with measurement and recording of the

Fig. 4

Figure 3: Fig. 4

forces required for such deformation. These forces directly determine the magnitudes of the components of the stress tensor at the corresponding point of the body.

The loading process of the tube found in this way, on the basis of the hypothesis of macrophysical determinacy, will be adequate to the loading process at the investigated point of a nonuniformly stressed body. In other words, the loading process is sought under the assumption that it is uniquely determined by the deformation process and does not depend on the gradients of the strain tensor. Such reproduction can be carried out for one or several points of the body in those cases where, on specimens, it is poss—

it is possible to reproduce the history of deformation without loss of stability by the specimen and without the formation of a neck in it. The method differs from that proposed in (2), in particular, in that it makes it possible to carry out the investigation for individual points of the body.

Let us consider an example of an investigation—the complex loading of a plate with a circular hole at the center.

A plate made of an aluminum alloy in the form of a cross (Fig. 1) was subjected to tension in the direction of the $y$-axis until plastic deformations appeared, and was then unloaded and stretched in the direction of the $x$-axis to the same values of the mean stresses $q$ in the weakened section. Each

**Fig. 4**

loading process consisted of five stages, at each of which measurements of deformations were made at points located on the axes $ox$ and $oy$. For these measurements, photoelastic coatings of ED-6M material were used in the form of continuous plates and narrow strips (the latter were used to determine separate values of the deformations). Both types of coatings were placed on symmetric regions of one and the same plate. In this way, deformation histories were obtained at each of the points indicated in Fig. 1 in the coordinates $\delta - \delta^*$ ($\delta$ is the difference in retardation in the continuous coating, proportional to the difference of the principal deformations $\varepsilon_1 - \varepsilon_2$, and $\delta^*$ is the difference in retardation in the coating cut into narrow strips, proportional to the quantity $\alpha\varepsilon_1 - \beta\varepsilon_2$, where $\alpha \neq \beta$ are coefficients determined by calibration and depending on the ratio of the strip width to its height and on Poisson' s ratio of the coating material).

As an example, Fig. 2a shows the history of deformation at point 5. From the fringe patterns shown in Fig. 3 for the corresponding loading parameters $\lambda_x = q_x/\sigma$ and $\lambda_y = q_y/\sigma$ ($\sigma$ is the proportionality limit of the material), or from the parallel measurements of optical retardation made with a compensator,

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the corresponding differences of principal deformations were found for all points of the field under investigation. (In Fig. 3, for $\lambda_y = 1.28$, the fringe pattern is shown as an example both in the continuous and in the cut part of the coating. It is seen that in the cut part the fringes are shifted relative to the fringes in the continuous coating.)

Let us note that in the fringe pattern obtained after the described successive loading of the plate in two directions and unloading $\lambda_y = \lambda_x = 0$, the influence of the complex character of the loading is clearly visible. If the plate had been subjected to simultaneous tension in two directions

with equal forces, the bands would represent concentric circles.

The deformation histories obtained for points 1–20 were then reproduced on tubular specimens made of the same material. As a result, loading histories were found for these points. As an example, Fig. 2b shows the loading history thus obtained for point 5. From the results of the investigations carried out, stress diagrams for $\sigma_x$ and $\sigma_y$ in the sections $x = 0$ and $y = 0$, respectively (Fig. 4), were constructed for the loading parameters indicated here.

Novosibirsk Institute
of Railway Transport Engineers

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*Note: Figure translations are in progress. See original paper for figures.*

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