Micrononuniformity of the stress–strain state of metals and alloys, manifesting itself in the process of loading in consequence of structural inhomogeneity, has a substantial effect on their mechanical properties, the fatigue limit, and the capacity for internal dissipation of the energy of vibrations. The assumption that there is a connection between internal-energy dissipation during cyclic loading and plastic deformation of the structural elements (blocks, grains) due to micrononuniformity of the state of stress was expressed by Davidenkov and later developed by Pisarenko [1] and Troshchenko [2]. Nonuniformity of the state of microstress in elastic cyclic loading of polycrystals may give rise to plastic deformations in individual microvolumes of the metal if the stresses in these microvolumes exceed the yield strength. Energy losses in unit volume of material per vibration cycle, connected with the origin of microplastic deformation, can be determined from the expression [2]

$$\Delta W = 2N_{K_{av}} \int_{\sigma_S} P(\sigma) d\sigma,$$

(1)

where $N$ is the number of grains in unit volume; $K_{av}$ is the mean energy content of the material; $P(\sigma)$ is the stress distribution function over the microvolumes. The integral $\int_{\sigma_S} P(\sigma) d\sigma$ characterizes the number of microvolumes in which the stresses exceed the yield strength $\sigma_S$ and plastic deformation occurs.

The form of the stress distribution function $P(\sigma)$ is determined chiefly by the structural inhomogeneity of the material. The cause of nonuniform stress distribution over the microvolumes in polycrystalline alloys not containing stress raisers of the type of pores or nonmetallic inclusions is elastic and plastic anisotropy of the grains with random crystallographic orientation. Since the number of grains in the material is large as a rule, a normal distribution is used as the function $P(\sigma)$ [1, 2]. That this assumption is correct for polycrystalline alloys is confirmed by experimental data on the nature of the distribution of local deformations over the microvolumes [3, 4].

Graphite inclusions in cast iron cause a high level of its damping capacity, but this damping capacity depends to a large extent on the shape, dispersity, and nature of distribution of the graphite in the bulk of the matrix. The greater damping capacity of cast iron compared with steel is due to the greater micrononuniformity of its stress–strain state upon loading due to stress concentration in the matrix near graphite inclusions. In consequence of the random distribution of the graphite inclusions, the microstress concentration is
also random. The presence of graphite inclusions causes a substantial change in the nature of stress distribution over the microvolumes of the matrix as distinct from the nature of the stress distribution in polycrystalline materials that do not contain inclusions, i.e., it affects the kind of the distribution function $P(\sigma)$.

Useful information on this problem can be obtained by examining the peculiarities of the distribution of local microdeformations in the matrix of cast iron with different forms of graphite.

The peculiarities of the distribution of local deformations in microvolumes of cast-iron specimens were studied; the cast iron was marked by different degree of ordering of the graphite inclusions. For the investigation, specimens of gray cast iron with disordered orientation of graphite, high-strength cast iron with spherical graphite, and high-strength cast iron with ordered orientation of nonequiaxial graphite were used. This last was obtained by rolling high-strength cast iron containing spherical graphite with 70% reduction. After the specimens had been made, they were annealed in order to eliminate the effect of the preceding treatment on the mechanical properties of the matrix.

Local deformations in the cast-iron microvolumes were studied by the polarization-optical method of photoelastic coatings. When thin photoelastic coatings whose thickness is commensurable with the size of the elements of the microstructure are used, then the localization of the method suffices for measuring the deformations within microscopically small regions [5, 6]. The local deformations were measured on an installation for polarization-optical investigations based on the MIM-8 series-produced metallographic microscope. The material for the photoelastic coating was epoxy resin with curing agent and plasticizer. The coatings were polymerized directly on the specimens. The technology that was used made it possible to obtain photoelastic coatings 10-15 \mu m thick.

The coated specimens were mounted in a strain device of the installation and loaded in pure bending, the surface of the specimens being photographed in plane-polarized light at different stages of loading with simultaneous recording of the bending force and the deflection. From the interference patterns, photographed in plane-polarized light, that had been formed in the photoelastic coating of the loaded specimen, the difference of the principal strains $\varepsilon_1 - \varepsilon_2$ and the angle of orientation of the principal strain axes $\alpha$ relative to the plane of polarization of the light were determined by using the expression

$$I = I_0 \sin^2 2\alpha \sin^2 k (\varepsilon_1 - \varepsilon_2),$$

where $I$ is the intensity of the light at the given point of the photoelastic coating; $I_0$ is the maximum intensity of the light; $k$ is a coefficient depending on the opticomechanical properties in the bulk of the coating.

Characteristic interference patterns originate in the photoelastic coating when the bending force corresponds to the point where the force–deflection diagram ceases to be linear, i.e., when plastic strain appears in the specimen. The smallest measured value $\varepsilon_1 - \varepsilon_2$ amounted to about 0.2%.

The values of the difference in the principal deformations $\varepsilon_1 - \varepsilon_2$, measured at different points of the surface of the specimen, were used for plotting fields of equal levels of $\varepsilon_1 - \varepsilon_2$ over the investigated part of the specimen (Fig. 1). The obtained fields of equal levels of $\varepsilon_1 - \varepsilon_2$ for specimens of cast iron with different degrees of ordering of the graphite inclusions indicate that the deformations are very nonuniformly developed in the microregions of the matrix. The nature of the graphite inclusions affects the distribution of local microregions of large and small deformations. For instance, in high-strength cast iron, sections with a high level of the difference $\varepsilon_1 - \varepsilon_2$ are situated along the inequiaxial graphite inclusions orientated approximately at an angle of 45° to the normal tensile stresses acting in the given cross section of the specimen and induced by the external load, i.e., also in the direction in which the maximum shear stresses act.

To compare the nature of the distribution of the microlocal deformations in specimens with different forms of graphite, distribution polygons (Fig. 2) were plotted. The argument of the distributions were the differences of the principal deformations normalized according to the mathematical expectation $(\varepsilon_1 - \varepsilon_2)_\text{av}$, where the value of $(\varepsilon_1 - \varepsilon_2)_\text{av}$ was determined by the formula

$$(\varepsilon_1 - \varepsilon_2)_\text{av} = \frac{1}{n} \sum_{i=1}^{n} (\varepsilon_1 - \varepsilon_2)_i.$$

In the matrix of high-strength cast iron with spherical graphite, the distribution of local deformations has a form close to symmetric; this indicates that there is an equal probability of regions of higher and lower deformations than the mean level. In the matrix of gray and of high-strength cast iron with inequiaxial graphite, the distribution of local deformations is asymmetric in nature, and in gray cast iron the asymmetry (shift of the mode relative to the mathematical expectation) is greatest. The asymmetry of the distribution curves