deformation in others. For deformation of the alloy 3V from the state of full plasticity with finish loadings $\mu_{\Delta\sigma} \geqslant 3$, an elastic relationship in the second principal (circumferential) direction is restored. Restoration of the elastic relationship results in a 20% rise in the strength of the material.

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MICROSTRUCTURES OF PULSE-HEATED TITANIUM ALLOYS

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UDC 536.33+539.319

A metal shows an increase in dislocation density near the point of action of a laser beam or a high-density electron beam. However, such studies have not been performed with heating by thermal radiation.

Here we report on the microstructures for OT4-0 and OT4-1 titanium alloys heated by thermal radiation. Increased dislocation densities are found in the surface layers, and slip lines occur in the grains.

The experiments were performed with specimens made from rolled sheets of thickness ($1-1.5 \cdot 10^{-3}$ m), which were heated to 1070°K by a thermal radiation flux of density $2.5 \cdot 10^5$ W/m^2 in an apparatus in which the radiation was provided by halogen lamps and the rise time to the maximum value was 0.5 sec. A specimen was a strip of width $3 \cdot 10^{-2}$ m cut from the irradiated sheet, with the end processed as a polished section prepared by mechanical polishing with abrasives, diamond paste, and electrochemical polishing. The section should be of good quality without erosion of the lateral edges, which contain most of the information on the microstructure, and there should be no signs of etching at a magnification of 600 in order to provide reproducible results in examining the dislocation structure. These requirements are met by polishing in an electrolyte of the following composition: 60% H_2SO_4,

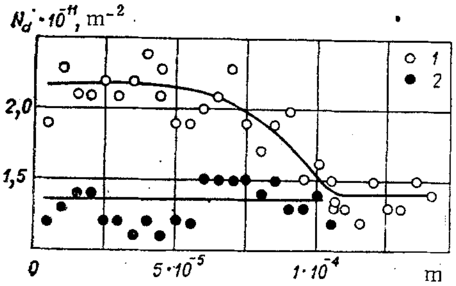

Fig. 1

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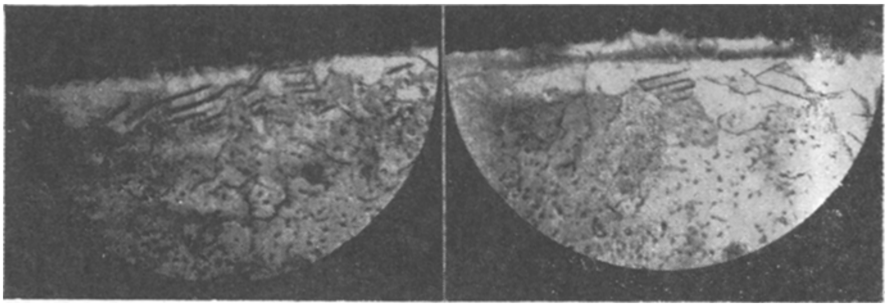

Fig. 2

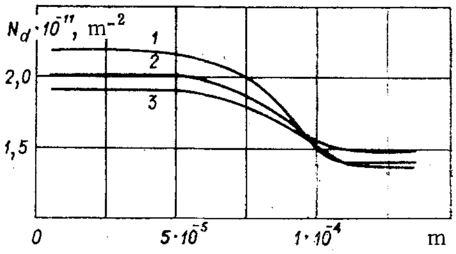

Fig. 3

30% HF of not less than 50% concentration, and 10% glycerol, voltage 33-37 V, 20° < t ⩽ 35°C, and distance between vertically placed electrodes about 0.2 m. The cathode was of Kh18N10T steel. The holder and the bath were made of PTFE-4. The rods in the holder bearing the section were clamped together by a force of the order of the yield point of PTFE. The duration of the polishing was 3-5 min. It is fairly laborious to develop a method of preparing a section with these features.

The dislocations were revealed by chemical etching in Keller's etchant [1] (21 cm^3 HF, 64 cm^3 HCl, 106 cm^3 HNO_3, and 160 cm^3 H_2O). Solution temperature 20°C, etching time 10-15 sec (specimen must be mounted in a holder). The dislocation structure is examined and recorded with an MIM-7 microscope.

The dislocation density is calculated as follows. The number of etch pits is determined on an area of 50 × 3 mm in the photograph beginning at the side surface (magnification 600). An STL table as used in examining spectrograms is used for convenience and to provide reliable counting. With this magnification, a distance of 3 mm on the photograph corresponds in the section to a layer of thickness $5 \cdot 10^{-6}$ m, so the dislocation density was determined over the cross section with an error corresponding to the difference in the dislocation distributions in a $5 \cdot 10^{-6}$ m layer, i.e., the section was divided into zones in the working direction. Figure 1 illustrates the dislocation distribution found in this way. The density in the irradiated surface layer is higher by almost a factor two (curve 1) than that in the main body (curve 2).

The dislocations were accompanied by microcracks emerging in the main normal to the surface. There was a considerable spread in the dislocation density from one point in the specimen to another and parts remote from the surface because of the inhomogeneity in the distribution, probably related to the rolling conditions. This type of effect was observed also in sections made for specimens that had not been heated.

The following point is notable. The irradiated layer did not contain grains with signs of slip such as occurs in grains in the shadowed surface (Fig. 2). The slip probably occurs at fairly high temperatures, when slip is facilitated and stresses arise from the inhomogeneity of the heating due to differences in optical parameters between parts of the surface. In areas where the absorption coefficient is high, the dislocation density in the surface layer is higher. Curves 1-3 in Fig. 3 correspond to parts with maximal, minimal, and average densities. Parts of the shadowed surface with signs of slip lie opposite regions in the irradiated surface with low dislocation densities. Slip occurs only in grains near the surface (within 2-3 times the linear dimensions of the grain), and was not seen in ones emerging on the surface. On the other hand, if there are inclusions in the region where slip stress relaxation occurs, the slip extends to a considerable depth (five or six times the linear dimensions of the grain). It is probable that slip is facilitated in grains near the surface.

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APPLICABILITY OF TIMOSHENKO-TYPE THEORIES TO LOCALIZED PLATE LOADING

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UDC 539.3

1. Introduction. Many calculations have been performed on localized loading for thin bodies of plate type. The basis is provided either by Kirchhoff's theory or by the nonclassical theories of plates of Timoshenko type [1]. It is usually assumed that the two-dimensional theories of plates are not applicable directly by the point of application [1]. This is due to the essentially three-dimensional state of stress near that point.

Here we examine the state of stress and strain in a thin plate by means of the three-dimensional and two-dimensional theories. The three-dimensional theory is characterized by a singularity in the displacements of r^{-1} type, where r is the distance to the point A at which the localized force is applied. The singularity occurs only for the front surface of the plate containing the point A. It is shown here that the displacements of points in the median plane are finite. However, if the thickness 2h of the plate tends to zero, the displacements of the points in the median plane acquire a singularity of the form of $\ln r_0$, where r_0 is the distance from the point to the point A_0 representing the normal projection of point A on the median plane. The coefficient to the singularity $\ln r_0$ will be called the intensity coefficient. If we consider the displacements of the points in the three-dimensional medium averaged over the thickness of the plate instead of the displacements of the median plane, they also have a singularity of $\ln r_0$ type, but the intensity coefficient differs from that for the median plane. For $\nu = 0$ (ν is Poisson's ratio), the difference in the intensity coefficients disappears.

We now consider the two-dimensional theories. According to Kirchhoff's theory, the deflection of the plate, which is identified with the deflection of the median plane, is finite and of order $O(h^{-3})$ if one assumes that the load is of order $O(1)$ and if we take the unit of length as the least dimension of the plate in plan. The intensity coefficient in the three-dimensional theory is $O(h^{-1})$. Therefore, if h is small, the solution from Kirchhoff's theory agrees closely with the three-dimensional one in the region $|\ln r_0| \leqslant CO(h^{-1})$, where C is a bounded function of r_0, i.e., at some small distance from the point $r_0 = 0$. The solution given by a theory of Timoshenko type differs from the previous in containing a singularity in the normal displacement of $\ln r_0$ type, and there is the question of comparing the intensity coefficients obtained from the three-dimensional and two-dimensional theories.

The following treatment is based on the theory of simple shells [2-4], for which the basic relations applicable to the theory of plates are given in Sec. 3.

2. Three-Dimensional Theory. We consider a problem discussed by Galerkin [5] for a rectangular plate loaded by a distributed normal load and freely hinged at the edges, where we make certain modifications. The plate is bounded by the planes x = 0, a, y = 0, b, z = ±h. The boundary conditions take the form

$$u_2 = u_3 = \sigma_1 = 0 \text{ for } x = 0, a, \; u_1 = u_3 = \sigma_2 = 0 \text{ for } y = 0, b; \tag{2.1}$$

$$\sigma_3 = \tau_{31} = \tau_{32} = 0 \text{ for } z = -h, \; \sigma_3 = p(x, y), \; \tau_{31} = \tau_{32} = 0 \text{ for } z = h. \tag{2.2}$$

If a localized force P is applied at the point (a/2, b/2, h), the surface load takes the form

$$p(x, y) = -\frac{P}{ab}\,\delta\left(\frac{x}{a} - \frac{1}{2}\right)\delta\left(\frac{y}{b} - \frac{1}{2}\right). \tag{2.3}$$

The solution according to [5] is expressed in terms of a biharmonic function $\varphi(x, y, z)$ as follows:

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