Finally, note that, using the formulas obtained, it is simple to calculate the dissipative function and the "temperature" energy-loss function $\chi \cdot \| \text{grad} T\|_T$, allowing the total rate of acoustic-energy loss in the finite volume both inside and outside the boundary layer to be determined.

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MODELING OF MOTION OF DISLOCATION TRAIN THROUGH DISLOCATION FOREST

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Modeling methods were used to analyze the motions of a train of dislocations through a dislocation forest. Differences were found in this motion in the basal plane of hcp crystals and in the $\{110\}$ plane in crystals of the NaCl type. It was established that the process of formation of dislocation loops when dislocations pass through a dislocation forest may be responsible for considerable strain hardening.

Forest dislocations are one of the principal factors leading to strain hardening. Accordingly, great attention is paid to this subject [1-12]. Investigations have shown that the penetrability of a dislocation forest for glissile dislocations, characterized by a coefficient $\alpha$, can vary over wide limits [13]. The value of $\alpha$ depends on a whole number of factors whose contributions are difficult to separate. In view of this it may be of interest to present modeling methods which, in particular, can be used to estimate $\alpha$ for a nonreacting forest [14, 15]. However, in [14, 15] the value of $\alpha$ was determined from the passage of one dislocation through a dislocation forest. The latter is somewhat of a simplification since in fact a system of dislocations moves through the forest. The coefficient $\alpha$ should, therefore, be evaluated from the possibility of a system of dislocations rather than a single dislocation passing through the forest. In this case, one should expect $\alpha$ to increase since after the passage of the main dislocations of the train, the dislocation forest may suffer "contamination" and become less penetrable to subsequent dislocations. In the present paper the effect under discussion is analyzed by modeling the process of a train of single-type dislocations moving through a dislocation forest.

The modeling was carried out for type-NaCl and hcp crystals with the following conditions.

1. For hcp crystals the dislocation forest was considered to consist of six types of screw dislocations with Burgers vectors $\pm 1/4 (112)$ and nine types of screw and edge dislocations with Burgers vectors $\pm 1/2 (110)$ for type-NaCl crystals. The forest dislocations were arranged in space according to a random law with one and the same occupancy density for each type and were assumed to be rectilinear and rigidly pinned.
2. The dislocations moving through the forest were assumed to be flexible and their shape was determined by the total field of stresses, of the forest dislocations $\tau^{\text{in}}$ and the external stresses $\tau$. The value of $\tau^{\text{in}}$ at each point of the glide plane was found as the sum of stresses set up by all the forest dislocations intersecting the model area $S$. In general complexity this corresponded to taking account of the contribution of about 500 forest dislocations at each point. With several dislocations moving through the forest, account was also taken of their interaction.

3. The self-stress of the flexible dislocations was taken into account in the linear-tension approximation.

4. The process of the motion of a dislocation train through a dislocation forest was considered as a chain of equilibrium positions, each of which corresponded to a particular, gradually increasing external stress.

5. The possibility of dislocation reactions occurring in the intersection of glissile dislocations with forest dislocations was not considered.

Within the framework of the formulated assumptions, at each point of the $i$-th glissile dislocation of the train the following condition should be satisfied:

$$0.5Gb^\kappa = b \left( \tau^{\text{in}} + \tau + \sum_{j<i} \tau^{ia} \right),$$

where $\kappa$ is the curvature of the dislocation line, $G$ and $b$ have the usual meaning, and $\tau^{ia}$ is the additional contribution to the internal field from the $j$-th glissile dislocation, expressed in terms of a contour integral along the dislocation line [16]. The complexity of the present problem, in comparison with that considered in [14, 15] consists in finding self-consistent forms of glissile dislocations since Eq. (1) is a system of integral equations. System (1) was solved by the iteration method by successively fixing the form of one dislocation and finding the equilibrium configuration of another. However, such an exact solution of the problem for curvilinear dislocations of an extremely complicated shape is onerous and takes up much machine time. Accordingly, in parallel we developed an approximate method of taking account of the interaction of glissile dislocations, basing ourselves on the fact that the additional contribution $\sum_{j<i} \tau^{ia}$ is equivalent to increasing the external stress acting on the $i$-th dislocation. Proceeding from this, in finding the configuration of the $j$-th dislocation at a stress $\tau$ for the $i$-th dislocations $(j > i)$ we assumed configurations corresponding to an external stress increased by 8%. In this case the glissile dislocations were assumed to be rigid. The self-consistent system (1) here reduces to a chain of equations which can be solved successively. This substantially simplifies computer calculations. Control computations showed that such an approximate method of taking account of the interaction of glissile dislocations yields results which practically coincide with the exact solution of the problem. At the points of the intersection of glissile dislocations with forest dislocations, at which there is a singularity, the solution of Eqs. (1) was found by the technique described in [14, 17].

Figure 1a shows the successive positions of the first basal dislocation in Zn moving through a forest as the external stress grows. It is seen that when $\tau^T = 36 \pm 1 \text{ g \cdot mm}^{-2}$ the first dislocation passes through a selected portion of the glide area $S$. In this case the value of $\alpha$ proves to be $1.09 \pm 0.03$. It is also seen that the first dislocation that passes leaves behind it a large number of dislocation loops encompassing groups of forest dislocations. Therefore, if a second dislocation begins to move at $\tau = 36 \text{ g \cdot mm}^{-2}$, then it should encounter that system of loops. Consequently, in order for the second dislocation to pass through the area $S$, it is necessary that the external stress be increased. The motion of the second dislocation is shown in Fig. 1b. It passes through the area $S$ when $\tau^T = 52 \pm 2 \text{ g \cdot mm}^{-2}$ which corresponds to $\alpha = 1.58 \pm 0.06$, i.e., a 45% increase in $\alpha$. The second dislocation also leaves which encompass the loops left by the passage of the first dislocation. Figure 1c shows the successive motion of the third dislocation which passes through the area $S$ at an even high stress, $\tau^T = 70 \pm 5 \text{ g \cdot mm}^{-2}$ ($\alpha = 2.13 \pm 0.15$). A further stringing of dislocation loops on groups of forest dislocations is observed. Therefore, at $70 \text{ g \cdot mm}^{-2}$ the fourth dislocation also cannot pass through the dislocation forest. However, when the external stress is increased to $\tau^T = 80 \pm 5 \text{ g \cdot mm}^{-2}$ the internal dislocation loops formed during the motion of the primary dislocations suddenly collapse and a fourth dislocation passes through a selected portion of the glide plane. Consequently, no further increase in the external stress is required for the passage of the fifth and subsequent trains of dislocations. When $\tau^T = 80 \pm 5 \text{ g \cdot mm}^{-2}$ there should be a stationary state from the point of view of some echelon of (0001) glide planes passing through the forest. The coefficient $\alpha = 2.43 \pm 0.15$ corresponds to this state. A high value of $\alpha$ was indeed observed in zinc and magnesium crystals [6-8, 10-12]. Thus, it should be assumed that intensive loop formation, occurring as the result of a pronounced irregularity of the field of internal stresses in hcp crystals, may be one of the factors responsible for the high values of $\alpha$ observed.