The condition of the material and the loading conditions have a substantial influence on the micromechanisms of fatigue crack growth and, as a consequence, on the rate of failure of metals. The condition of the material is determined by the degree of alloying, the phase composition, the microstructure on the dislocation and metallographic levels, the grain size, and the quantity and distribution of the interstitial impurities. The loading conditions include the stress ratio, the frequency, the average or maximum cycle stress, and also the form of the cycle and the condition of the surrounding medium. Despite the fact that the frequency of cyclic loading is one of the most important parameters, taking into consideration of which is necessary both in laboratory tests and in calculations of the life of structural elements, the question of the relationship of the characteristics of fatigue failure to loading frequency has been insufficiently studied. This is indicated by the fact that of 64 empirical expressions describing fatigue crack growth rate [1] only one [2] contains loading frequency. Experimental investigations of the influence of cyclic loading frequency of the characteristics of fatigue crack propagation are limited, as a rule, to comparison of failure macrorates [3-9]. The number of works devoted to study of the influence of loading frequency on failure micromechanisms is insignificant and the data obtained is contradictory [10-17]. In this report an evaluation is made of influence of loading frequency on the fatigue failure micromechanisms of commercially pure titanium.

Material and Method of the Experiment. The chemical analysis in % and the mechanical properties of the investigated alloy were 0.20 Fe, 0.08 Si, 0.05 C, 0.10 O, 0.04 N, 0.008 H, 0.10 other impurities, $\sigma_t = 378$ MPa, $\sigma_{0.2} = 315$ MPa, $\delta = 35.4\%$, and $\psi = 80.6\%$. The loading frequencies were 140 and 600 Hz and also 3 and 10 kHz. The specimen dimensions (Fig. la) were the same for all loading frequencies and provided fulfillment of the condition of plane strain at the crack mouth during the whole investigated period of its propagation. The constant humidity of the air and the corrosion resistance of the alloys made it possible to eliminate the influence of the surrounding medium on the frequency relationship of the crack growth rate.

For the purpose of studying the influence of cyclic loading frequency on the fatigue crack growth mechanisms in each of the regions of the kinetic fatigue failure curve obtained with fixed values of the stress intensity factor macro- and microfractographic investigations and an analysis of the dislocation structure directly in the zone of fracture were made. A special method of simultaneous aimed obtaining of foils and oxide replicas from the undamaged fracture surface was developed for solution of the latter problem. Three mm discs cut from the specified portion of the failure surface were ground and electropolished on one side while the other side of the disks, which was the fracture itself, was covered with a special protective film which after electropolishing was removed by solution. The electropolishing method made it possible to simultaneously obtain on the same side of the disk sufficiently "transparent" area for investigation of the dislocation structure and areas of oxide replicas used for a detailed analysis of the failure surface relief. The foils obtained were investigated in an electron microscope with an accelerating voltage of 1000 kV and some portions of the oxide replicas in an electron microscope with an accelerating voltage of 150 kV.

Results of the Experiment. Since the previously conducted analysis of literature data showed that even for alloys of the same base the kinetic fatigue failure curves are described by the Paris equation

$$v = \frac{d\ell}{dN} = C(\Delta K)^n$$

Fig. 1. Specimen for tests in the 140-10,000 Hz frequency range with the plan of cutting of the investigated portions of the fractures (a) and kinetic fatigue failure curves of commercially pure titanium tested at loading frequencies of 140 (1), 600 (2), 3000 (3), and 10,000 (4) Hz to auxiliary (b) and logarithmic (c) coordinates.

With the exponent \( n \) changing within the limits of several units (for example, 0.5-2.5 for titanium alloys [19]) the results of the cyclic crack resistance tests were first presented to somewhat changed auxiliary coordinates of \( \Delta K - \Delta K/\sqrt{v} \), where \( v \) is the rate of development of the fatigue crack in m/cycle [20] (Fig. 1b). The use of the auxiliary coordinates made it possible to distinguish the region of the quadratic relationship of crack growth rate to the stress intensity factor (in Fig. 1b the horizontal region) and to graphically determine the value of \( n \) and \( C \) in Eq. (1) for the remaining regions of the curve more accurately than with logarithmic coordinates. Then the curves obtained were drawn to normal logarithmic coordinates (Fig. 1c). The kinetic fatigue failure curves of VT1-0 alloy constructed in this manner consist of three branches, two of which are of the center region of the curve. On the curves there are no regions corresponding to high rates of crack growth rate. This may be explained by the fact that at the loading frequencies studied in the area of high crack growth rates failure of the specimen occurs during a very short time interval, as the result of which difficulties arise in accurately counting the number of cycles corresponding to certain crack lengths.

The data presented indicates that with an increase in loading frequency all regions of the curve are preserved, shifting into the area of lower crack growth rates. The abscissa of the point of the bend on the center region corresponding to the start of the quadratic relationship of crack growth rate to \( \Delta K \) remains constant for all of the loading frequencies.