Earthquake as kinetic process

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[1]Institute of Geophysics, National Academy of Sciences of Ukraine, Kiev, Ukraine
groza@igph.kiev.ua
[2]National Aviation University, Kiev, Ukraine
valentina.groza@gmail.com

1. At present time the forecast of earthquake is one of the most actual problems of geophysics and to a considerable degree one of the primary tasks of Earth physics. The basic unresolved question of the earthquakes forecast is the prognosis of time of strong earthquakes occurrence. There are three models: dilatant-diffusion model, avalanche-unstable fracture model and stick-slip model. Unfortunately, while adequately describing the development of earthquakes, these models cannot predict earthquake. Actually they are only scenarios of earthquakes. At the same time it is essentially important that all these models consider ***earthquake as a process***. The models in question are based on solid mechanics and the physics of rock fracture. We propose the other approach based on thermodynamics, phase-transition theory and chemical kinetics. It allows to enter explicitly time into description of the process due to Arrhenius equation (as activation time). For elementary dislocation it is 10^{-13} s.

2. The kinetic approach allows to explain why aftershocks relaxation (Omori's law) has hyperbolic character and considerably differs from standard exponential relaxation of mechanical systems. The combination of the Boltzmann distribution law (statistical thermodynamics) and the Arrhenius equation (chemical physics) gives Omori's law ($N \sim t^{-1}$) directly.

From the same standpoint the role of fluctuations in the relaxation processes has been also analysed. Taking into account fluctuations it is necessary to replace the standard relaxation equation by

$$\frac{d}{dt}N = -\frac{N}{\tau_{\text{relax}}} + \phi(t)\sqrt{N} .$$

The solution is "stretched exponent", that is has long (hyperbolic) tail.

The kinetics of relaxation to equilibrium is limited by the speed of establishing the concentration fluctuations, which depends on the diffusion. In this case relaxation has character $N \sim t^{-3/2}$ instead exponential [Zel'dovich, Ovchinnikov, 1977]. Thus, in the real process $N \sim t^{-C}$ and $C \in [1;1.5]$.

3. The kinetic approach allows to look at diffusion in the crystals in the different way. The basic idea is that the diffusion process is not continuous — each act of displacement is accompanied by a relaxation. If Fick's law is explicitly added by the relaxation term, then instead of the diffusion equation the cable equation is obtained (it is similar for generalization of Fourier law realized by Cattaneo). Here it is essentially important that the problem of infinite rate of diffusion in this case disappears.

4. The solid rupture is traditionally considered as critical event, and strength is accepted to a constant of solid. Experience shows that it naturally depends on time and temperature. At present it is possible to state that such ***a limit of strength does not exist***. Tensile stress (load) p, fracture time τ and temperature T are uniquely related to each other [Zhurkov, 1968]:

$$kT \ln \frac{\tau}{\tau^*} = U - \text{const } p \ .$$

According to Russian Academician S. N. Zhurkov, the mechanism of rupture is connected with thermal fluctuation dissociation of bonds responsible for the strength. The sense of thermal fluctuation mechanism is that the potential barrier interfering rupture of bond is overcame due to of energy fluctuation. I. e. it is takes place over-barrier transition with characteristic exponential dependence of expectation time on temperature.

Our approach consists in the fact that transition occurs not due to the activation (energy excess), but due to the decrease of barrier height. The background is that the Zhurkov formula is equivalent in fact to ordinary thermodynamic relation

$$t = t_* \exp\left(\frac{\Delta G}{kT}\right).$$

The Gibbs "free energy" G has the physical dimension of energy but it is not energy per se. The Gibbs function is the pseudo-potential, which shows the natural direction of the dynamics of a thermodynamic system. The surface tension is defined is as $\gamma = \left(\frac{\partial G}{\partial s}\right)_{T,p,N_i}$. Reducing the height of the barrier means that the slope of the tangent to the barrier top decreases (in other words, the surface tension decreases). It is possible state the reverse — decreasing of surface tension reduces the height of the energy barrier. Since the surface tension is associated with the work expended to rupture of intermolecular bonds, then it is caused by these with bonds and inversely. Actually, γ is represented as ***work*** (per unit area) — cohesion work, i. e. it is a measure of intensity of work necessary for rupture. There are many reasons of decreasing the surface tension and thus reducing the strength, that is why it is difficult to define the strength limit uniquely.

References

Zhurkov S. N. Kinetic concept of solids strength // Bul. Academ. Sciences of the USSR. — 1968. — № 3. — P. 46—52 (in Russian).

Zel'dovich Y. B., Ovchinnikov A. A. Asymptotic of establishing equilibrium and concentration fluctuations // J. Experiment. Theor. Phys. Lett. Theoretical Physics. — 1977. — **26**, № 8. — P. 588—591 (in Russian).