EARTHQUAKE’S SHOCK-WAVE MODEL AS TO THE REGION SEISMIC HAZARD EVALUATION

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RESUME

The earthquake’s shock-wave model is a fundamentally fresh hypothesis, its essence is that the shock wave is initiated deeply inside the Earth, then it is propagating through the lithosphere, thus forming the earthquake’s source. Arriving at the Earth surface the shock wave is reflected from it producing the unloading (strain) wave. The interaction of the shock and the unloading waves generates ruptures, fractures, ets. With numerical models of continuum medium mechanics this insight into the earthquakes allows to evaluate the region seismic hazard, namely to calculate the amplitudes and velocities of the medium slips, that are accompanying the arrivement of the shock wave at the Earth surface. According to this model, the earthquake source is defined as a volume of the coherent and acoustically active medium with the far order in which the opening cracks are interexchanging the acoustic waves. Inside this volume the shock wave is generated and then it is propagating.

INTRODUCTION

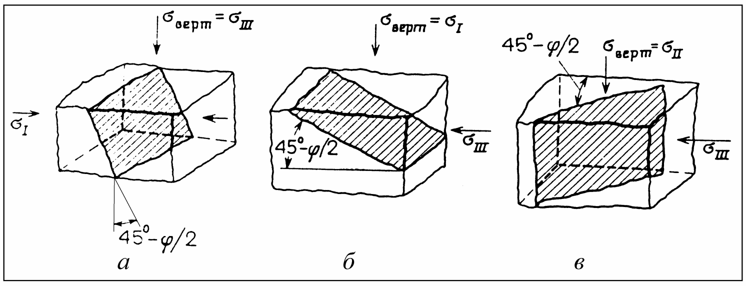

Fig. 1. Coulomb-Mohr’s fracture criterion.

The value of θ increases from 0° to 45° as the depth h and the lithostatic stress σ increases. This results indicates as the far order as the earthquakes do not occur inside the medium, possessing only the lithostatic stress. The exceptions to this conclusion are possible only just for large values of σ (σ >> 5 kbar), here the value of φ is very small and the angle of cracks opening θ ≈ 45°. If the values of σ are smaller, then θ should be less than 45°, but the occurrence of the far order at this medium requires the appending the value of θ to the necessary value of 45°. This appending is possible by the means of the lateral, tectonic stress (Fig. 2-c). Just this stress, initiated by the global tectonic factors, ends in the rupture formation, the drift ot the plates and continents.

Let’s consider the case when θ depends on the lithostatic stress and the stress at the subduction zones. Here σ results from additive superposition of two stresses, acting at an angle together. Figure 2-d shows the generation of the far order and of the space coherence through the moderate additional stress. This example depicts the possible action of the trigger-effect at our model this effect is discussed in seismology.

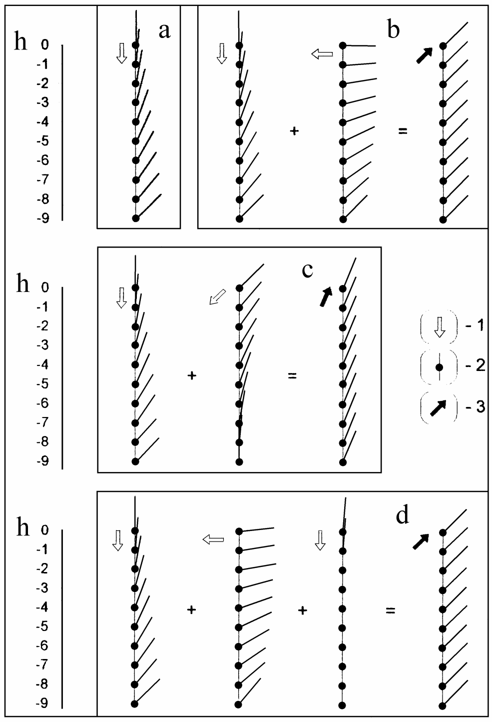

Fig. 2 Initiation of the far order inside the geologic medium under the change of the angle of the cracks origin and the change of the load effect [1]: a) vertical, lithostatic; b) lithostatic + lateral; c) lithostatic + “under angle”; d) also b + addition external. The far order and space coherence origin in “b, c and d”. 1 is the direction of the load action, 2 is the position of the crack and its direction, 3 is the space coherent direction.

THE ROCKS’S ACOUSTIC SPONTANEOUS RADIATION PROCESSES.

The experimental data on the acoustic emission within the stressed sample of the rocks reveal [5, 16]; that an explosion-like increasing (a chain reaction type) of a number of cracks (sound impulses) N per the time unit t (where $dN/dt \sim N$) develop at the sample at some occasional moments of time, this increasing is avalanche-type there is a know similar phenomena in optics, namely, the acoustic spontaneous radiation process of Dicke in laser physics, the author proposed [4], that the two-level system should spontaneously turn into a ground through the time, inversely with the number of the excited radiator N: $\tau \sim N^{-1}$.

THE SHOCK-WAVE MODEL’S MAIN CONCEPTS.

Let’s consider different approaches to solving the problem of the shock-wave model and to estimation of the seismic hazard: mathematical, physical, geophysical and numerical.

<u>The mathematical approach.</u>

The problem conditions involve as the determined positions of the cracks and as the known law of their interaction, the time character of the movement of the front of the avalanche-type formation. This approach is the Cauchy problem is existent and unique, and as the solving is initial conditions dependent.

<u>The physical approach.</u>

The approach requires to check if the postulated mechanism of the cracks interaction results in the break solution, outcoming in the generation of the shock wave at the quasi stationary acoustic phone.

The solution of the Fokker-Planck equation is responsible for shock wave generation

The self-organizing systems which incorporate the system of interaction and opening cracks are governed, as a rule, by the differential equation of Fokker-Planck. These equations are known to describe the process of the self-organizing systems. The physical essence of the self-organizing mechanism involves the interaction of the two processes of transport: drift and diffusion (percolation). Both these processes occur in our model. The stationary solution of the Fokker-Planck equation as results in relationship of the correlation length to the impulse flow density, and as makes possible to estimate the fractal dimension taken as flicker-noise (The well known seismologic Gutenberg-Richter law is the flicker noise too).

The unstationary solution of the Fokker-Planck equation results in breack solution of the delta function type of in the shock wave formation [11 – 13].

The shock wave formation as a solution of Korteweg-de Vries's equation

Theoretical aspects of the shock wave formation resulting in comulation of many impulses, are discussed in [7], here the shock wave is described by the equation, accounting for the nonlinearity, dispersion and medium dissipative features. The Korteweg-de Vries's equation introduces to a wide class of the like phenomena [6]. The application of this equation to the solving of the problem of shock wave earthquake model is discussed in [9].

The shock wave formation through the intercrossing of the like characteristics

The characteristics' method one of the known number methods of the solution of the Cauchy problem, is applicable for the solving of the shock wave formation problem. In our case the vector of the acoustic wave speed dx/dt is taken as the characteristic (see the insert at the left corner of the Fig. 3 [3]). The vector intesection at some point (or region) results in break solution, generating the shock wave formation.

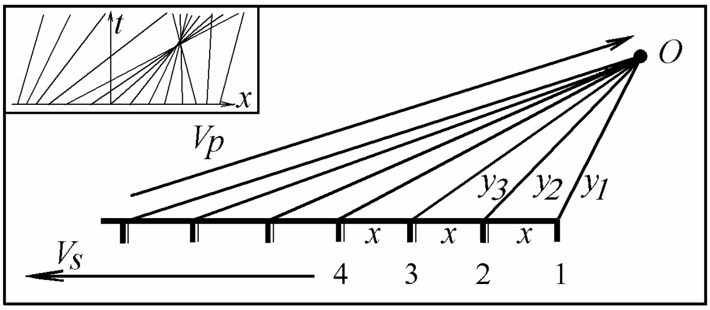

Fig. 3. The coherent addition of P-waves (at the point 0) produced by the opening of cracks (here 1, 2, 3, 4 are wide vertical strips, thin strips are microcracks) through the S-wave propagation.

Now suppose, that the structure of the cracks and microcracks, parallel to each other is formed inside some volume of the stressed rocks. The opening of the microcrack is accompanied by the S-wave emission, then after its dissipation by crack, the P-wave and S-wave are reemitted, the directions of their propagation are: along the cracks orientation – for the P-wave, and transverse to the P-wave rays – for the S-wave. Subsequently the dissipation of the S-wave by the microcrack produces its opening, and the just listed phenomena replicate. As a result in this volume there are formed a quantity of the P-waves, which are propagating along the cracks orientation with the speed V_P and a quantity of the S-wave, which are propagating transverse with the speed V_S.

The shock wave arising is related to the phenomenon of the intercrossing of the like characteristics. The simplest example of this phenomenon is the formation of the so-called centrary wave, here some usual wave, concurrently propagating intercross at one point (O) – the top of the wave (Fig. 3). There with the wave of compression, in which both density of the medium substance and the pressure at the wave are increasing, is arised. The wave of this sort should be shock.

The geophysical approach.

Together the nature of the earthquake, so its prediction are the main problems of modern geophysics. The supposed shock wave model is conceptually new, but taking in the commonly accepted approach of the avalanche formation of cracks, the difference is in the following generation of the shock wave, but not in the formation of the huge crack. With the knowledge of laws of the shock wave propagation within the continuum medium, of the geodynamic situation (it is defining the angle of the shock wave arrivement at the Earth surface), of the seismic region section, and of the soil state equation it is possible with much assurance to estimate as the possibility of the earthquake occurrence in the given region, so the amount of the soil destructive movements through the shock wave arrivement at the Earth surface.

The discussed approach should be taken to be analogous to the microseismo-regioning. If the earthquake is of necessary and it is too dangerous, the artificial barrier to the shock wave arrivement at the protective object is essentially real.

The numerical approach.

The numerical methods in mechanics of the continuum medium have been developed by the academicians N.N.Yanenko and S.K.Godunov at the Siberian Branch of the Academy of Science to solve the war problem. The package of methods and programs was applied to solve the problems of gaseous dynamics with large deformations including the processes of detonation of the explosive substances and the shock wave in metals [1].

The numerical approach to our problem involve the adoption of the numerical methods to the solving of two dimensional (subsequently, three dimensional) problem of the shock wave propagation, through the geologic medium and to the solving of the problem of the shock wave arrivement at the Earth surface. The main difficulty resides in selecting the most suitable equation of the soil state and the seismic region section.

THE ARRIVEMENT OF THE SHOCK WAVE AT THE SURFACE

Let's consider the falling the shock wave on the free surface at the angle α. This angle corresponding to the direction of the main shock of the earthquake by the seismic data, lies between the limit 40 - 50° at horizon. For example, α was equal to about 50° for the earthquake in Spitak (1988, Armenia). Angle α was equal about 40° for Northridge earthquake, which just didn't destroy Hollywood (1994, USA, California). The earthquake with the non-vertical falling of the shock wave commonly feature the non-coincidence of the earthquake source (epicentre, as the earthquake's hypocentre projection) with the region of the maximal destruction. The Northridge's destruction diagram substantiates the foregoing here the epicentre was clear of the region of the maximal destruction [15]. The dsimilar situation was in Spitak, and many other earthquakes.

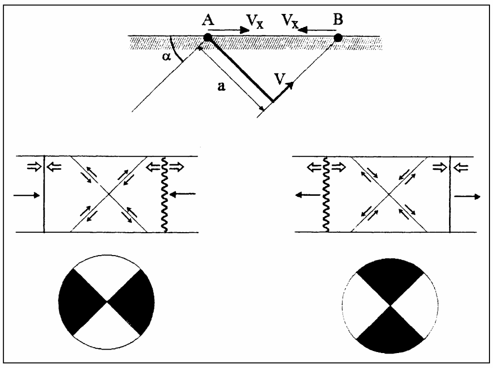

Fig. 4. The waves interaction through the non-vertical falling of the shock wave on the surface.

Let's consider the effect of forces and stresses occuring inside the space of interaction between the shock waves and the unloading (strain) waves in the case of the nonvertical falling of the shock wave (Fig. 4). The shock wave front arrives at the Earth surface from below at the angle α and the speed V and at the surface point A the shock wave generate the unloading wave, which starts to propagate in the direction, opposite to the shock wave.

Thus, two waves the shock wave and the unloading wave issue out of the point "A", with the speed V_X in the opposite directions. The size a of the shock wave front governed by the sizes of source is finite. Thus it is the point B, in which the unloading wave would completely arrive at the Earth surface.

The interaction of the shock compression wave and the unloading wave generates the tension and compression efforts opposite in signs, effecting the ruptures, fractures, ets of the Earth surface. The ruptures and fractures coincide with the nodal planes, which separate the zones of compression and tensions. The fixed by seismostations surface waves initiated by the ruptures and fractures, coincide with the directions of compression – tension in phases. At the source volume the zones of compression – tension are formed similarly here the shock wave are splitting, hence the unloading wave is generated at the acoustic boundaries (the differences in densities and in the speed of propagation of the seismic waves).

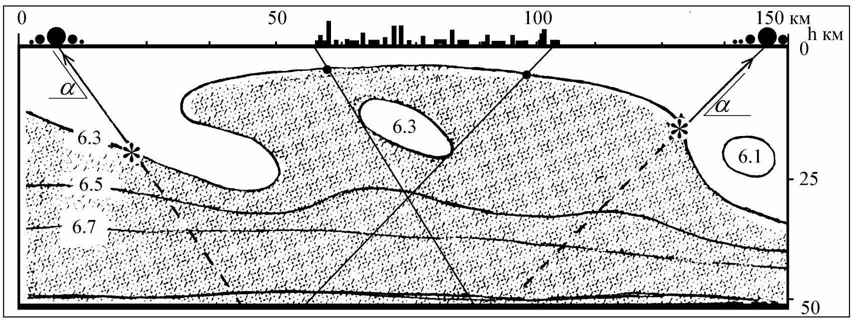

Fig. 5. The seismic section of the Earth's crust at the Muyi region of the Baical rift zone derived from the velocities of P-waves [8].

CONCLUSIONS.

Let’s present an example, validating our approach to earthquake physics and earthquake’s shock-wave model as the region seismic hazard evaluation (city, dams, nuclear electric stations) for legitimacy. Figure 5 shows the manner in which the applying of the shock wave model of the earthquake, numerical simulation and seismic cutting allows to evaluate the seismic hazard (or the degree of the safety) of the “city” (50-100 at the Fig. 5), located at the seismodangerous region. Let’s α is the angle of the main shock of the earthquake at this region.

At the right part of the figure there are the distructions by the Muyi’s earthquake in 1957, at the left part – by the Northbaical in 1917. The asterisks at the seismic boundary of the highvelocity geologic body are the hypocenters of the distructivee earthquakes. The circles at the surface show the regions of distructions. Between these regions there is a “city”, protected by the low velocity zone “6.3” against the earthquake.

The developed approach is in line with the seismic data for the powerful earthquake in Northridge (1994) and Kobe (1995) the statement is notably true for the part of our model which is concerned with physics of the strong motions of the Earth crust, caused by arrivement of the shock wave at the Earth surface. This arrivement of the shock wave is defined by analytical equations, which should be solved numerically. The data on the seismic section of the Earth’s crust allows to solve numerically the problem of the generation of the volume waves, which are emitted by the source and subsequently accepted by far seismostations. There is question: if the geologic stressed medium is free to turn into a source of the shock wave generation. This problem requires further solving by numerical methods. There are physical prerequisites to the shock wave generation within the geologic medium. The application the characteristics method and the solving of the Korteweg-de Vries’s and Fokker-Planck equations provide the means for tackling the given above question. A more penetrating into the earthquake physics possibly would the ways of protection against distructions by destroying of the shock wave front of the artificial obstacle.

The supposed shock wave model of the earthquake consider the mechanism of crack – wave – crack interaction. This mechanism should evidently appear at the depths not more than 30 km. At the greater depths litosphere with great time of relaxation shows itself as liquid, and thus the mechanism, resulting in the cracks formation, is not applicable. Possibly at the greater depth the dumping of the tectonic energy is accounted for by the liquid boiling and the bubble formation. Then the mechanism of the bubbles collapsing as well as the cracks opening would generate the shock wave.

REFERENCES

[1] Agureikin V.A., Krukov B.P. (1986). Method of individual particles for calculation of highly deformed multicomponent continuum flows. Num. Mech. Continuum Med. 17. 17-31

[2] Aki K., Richards P.G. (1980). Quantitarive seismology. Freeman and company. San Francisco

[3] Bressan A. (2000). Hyperbolic systems of conservations laws: the one-dimensional Cauchy problem. Oxford University Press Inc. New-York.

[4] Dicke R.H. (1954). Coherence in spontaneous radiation processes. Phys. Rev. 93. 99-110

[5] Zhurkov S.N., Kuksenko V.S., Petrov V.A. et al (1980). Concentration criterion of volume fracture of solid. In Physical Processes in Earthquake Foci. Moscow. Nauka. 78-86

[6] Zaslavsky G.M., Sagdeev R.Z. (1988). Introduction in nonlinear physics. Moscow. Nauka 368

[7] Zeldovich J.B., Raizer Iu.P..(1966). Physics of shock wave and high temperature hydrodynamic phenomena. Moscow. Nauka, 686

[8] Krilov S.V. et al. (1993). The detail seismic investigations of lithosphere by P- and S-waves. Novosibirsk. Nauka

[9] Kuznetsov V.V. (1992). The physic of Earth’s catastrophic phenomena. Novosibirsk. Nauka 92

[10] Kuznetsov V.V. (2001). Model of self-organization of an ensemble of cracks radiating sound. JAMTP. 42, 720-724

[11] Kuznetsov V.V. (2001). Shock wave model of earthquake. Earth’s sience. Seismology. Moscow. Vuzovskaij kniga, 47-62.

[12] Kuznetsov V.V. (2002). The physics of hot Earth. Moscow. Vuzovskaij kniga

[13] Kuznetsov V.V. (2002) Shock wave earthquake model. Vulkanologia i Seismologia (in press) [14] Paul B. (1968) Macroscopic criteria of plastic flow and frail fracture. Fracture. Academic Press. New York. London

[15] Harp E.L., Jibson R.W.(1996). Landslides triggered by the 1994 Northridge, California, earthquake. BSSA, 86, S319-S332

[16] Lei X., Nishizawa O., Kuzunose K., Satoh T. (1992). Fractal structure of the hypocenter distributions and focal mechanism solutions of acoustic emission in two granites of different grain sizes. J. Phys. Earth. 40, 617-634

[17] Reid H.F. (1911). The elastic-rebound theory of earthquakes. University of California Publ. Geol. Sci. 6, 413-444

[18] Rial J.A., Saltzman N. G., Ling H. (1992). Earthquake-induced resonance in sedimentary basins. American Scientist. 80, 566-578