Geophysical Research Abstracts, Vol. 7, 03882, 2005
SRef-ID: 1607-7962/gra/EGU05-A-03882

Acoustic emission measurements to simulate seismicity triggering effect by impacts of physical fields

V. Bragin (1), A. Avagimov (2) , A. Alad'ev (1), L. Bogomolov (1), A. Zakupin (1), V. Sychev (1)

(1) Research Station of Russian Academy of Sciences in Bishkek, Kyrgyzstan

(2) Institute of High Energy Densities RAS, Russia

(bragin@gdirc.ru / Fax: 996 312 611459)

Introduction

Numerous examples of effect of seismicity triggering by natural or man-caused vibrations may be considered as a demonstration that some technological actions to seismic generating structures in order to prevent strong earthquake are accessible [1]. The idea of nonexplosive vibroseismic triggering of week seismicity to quicken the relaxation of tectonic overstresses and therefore to reduce the hazard of catastrophic earthquake become more and more attractive. It is well known that Acoustic Emission (AE) is a good indicator of inelastic straining processes and microfracture of terrestrial material. It was used in our previous experiments with marble and granitic specimens under creep test in presence of weak vibrations [2]. The results of this work may demonstrate the examples of vibration triggered growth of straining rate and AE activity of loaded solids: laboratory tested specimens, rock massifs in the terrestrial crust. Presently we focus our efforts to record the AE of loaded specimens of terrestrial materials to understand the principles of seismicity triggering by physical fields applied externally (not only vibrations). Developing the idea of reactions of stimulated rock samples, new set of experiments using the spring rheological press with the strength up to 100 tons were carried out. The aim was to reveal AE in the sample of granodiorite excited by an electrical pulse of high energy (capacitor source) Our approach to seismicity simulation involves conducting long duration rheological tests while making high frequency measurements of strain and acoustic emission (AE). This enables us to maintain a similarity between our laboratory experiments and earthquake nucleation - in both situations there is a slow phase of energy accumulation as well as a fast phase of energy release. Experiments have been performed on pristine samples of rock subjected to creep tests under uniaxial and biaxial compression. The load has been maintained constant for long periods by placing a spring in series with the samples in a standard hydraulic press. Step changes in load have been imposed using the hydraulic press. Stress, strain and acoustic emissions have been recorded using a broad-band measuring system.

Results of modeling.

Represented results of the work involve the investigation of AE "responses" to the action of additional power fields over strained rocks. The examples of AE responses of rocks and concretes specimens have been considered. AE responses to external power impacts are marked to occur at definite band of values of main compressive load. The correlation of AE activity of terrestrial materials specimens with electromagnetic and vibration impacts applied externally has been revealed on the base of responses analysis. Rapid growth of AE activity caused by electromagnetic impacts usually occurs with some delay after the beginning of electric pulse. One can distinguish such spikes of AE activity (and to specify them as delayed responses) on the background of random fluctuations of AE, because the change of AE due to electromagnetic impacts exceed the level of dispersion. All these results were obtained during experiments on specimens of various materials: granite, granodiorite, gabbro, quartcite, galite as well as special heteroheneous materials (concretes with inclusions) simulating geological media. This speaks in a favor of generality of effect of AE vibrosensitivity and electrosensitivity, since the effect was observed on specimens of various physical-chemical structure, the rheological and strength properties being different also. It has been found while experimental studies that the effect of electromagnetic field on strained structures has different modes depending on the source of EM field, the specimen material, the value of main load, and the time of specimen exposure under this load. The superposition of these factors predestines the kind of response to electric impact, particularly the variations of responses specific parameters. Taking into account the rate of response rise and subsequent drop one can assume that the response arises inside domain with locally strained structure, and this entails the avalanche defects formation there. Generally two types of response to electromagnetic power action may be specified. The first type corresponds to observations of short-term increase of AE activity. In this case the activation front is quite sharp. Usually such responses were recorded when the sample is overburden by compressive load of moderate value. The second type of responses may be specified by steady increment of AE activity. The enhanced level of AE remains steady during long time after electric impact. During repeated electric impacts at the same stress the responses of first type reduce: we have recorded minor or marginal their manifestations or don't observe any such repeated response at all. The fact indicated above resembles well-known Kaiser effect. The similarity of observations to Kaiser effect may be formally described as the absence of detectable AE events until the load imposed on the material exceeds the previous applied level. In this regard the experimental data analysis on peculiarities of Kaiser effect in loaded rocks under external power actions has been performed. It was outlined that acoustic emission events are detected only during the first loading to given compressive stress and responses more distinctive after first electromagnetic impacts at the same loading level.

It should be noted that the creep test condition (when the constant value of stress is supported by compressed springs) is the most unfavorable to observe the effect of electromagnetic triggering. Energy influx is superimposed on relaxation processes under the condition of constant strain rate (so the state of the tested specimen tends to be metastable and hence sensitive to external perturbations like tat of electromagnetic pulses. Meanwhile pure relaxation is to take place under constant loading condition as long as the value of load is below fracturing (when cracks growth becomes strengthen than relaxation). Such relaxation involves rock mechanics aspect (reduction of local stress concentration within tested specimen) and electric relaxation (change in electric polarization). Creep tests of rocks specimens have demonstrated that the effect of AE activation due to electromagnetic pulses is not so apparent as in the case of constant strain rate test [3].

Our experiments revealed such peculiar feature of AE activity reaction to electromagnetic impacts as its degradation when repeated power action occurs (tendency like weakKaiser effect). This phenomenon looks as follows: the response of AE activity to the second time voltage supply (repeated generator power on) is minor in contrast to that correspondent to first time power on. No visible response to third time electric bias took place. Only after long exposure of tested specimen its AE activity becomes again sensitive to electromagnetic impacts. Meanwhile, under condition of constant rate straining the reaction of AE to consecutive voltage power on was well reproducible [3].

New approach for triggering simulation.

Special experiments were conducted to confirm that influx of mechanical energy is the cause of different modes of acoustic activation effect stimulated by similar electromagnetic pulses but under different straining conditions. Motivated in part by the concept that even small stress or strain increments can contribute metastable state we arranged vibration sessions on our loading machine, by fastening a small size vibrator (buzzer) to the lateral surface of the specimen being tested. Sinusoidal AC signals of the G3-112 generator were supplied to the input of a vibropack for exciting vibrations of a given frequency. During the vibration session, we controlled the constancy of amplitude and frequency of the electric signals supplied to the vibropack. By this way we tried to simulate dynamic component of load (always being present under constant rate straining). Although such simulation is too rough, combination effect of dynamic loads (weak vibrations) and electromagnetic pulses is worth analyzing. We observed the distinct reaction of acoustic emission of concrete sample to combined action of electric pulses and vibrations: At first power impact test (2000-8000 s) we initially turned on the source of electric pulses and then the vibropack. Vice versa order of power on corresponds to the second test period (12000-20000 s). In both cases the response of AE activity to combined vibroelectric action exceeds the superposition of typical acoustic responses (for given material and given conditions) to separate action of electric pulses and vibrations. The increment of AE activity in the second case is less that that in the first. This may be correspondent with general responses degradation tendency mentioned above.

The obvious result of combined power action: - growth of AE response above a simple superposition of reactions to every power impact, - shows that it is worth to look for similar cooperative effect in the case of several sources of electric field pulses (bielectrical action). In our experiments we distinguished two modes of such actions: alternate power-up of the several sources of EM field and simultaneous operation. Correspondingly, the realization of the second mode of power action requires EM field sources with special characteristics (outputs high isolation etc.) Note that the results of both modes of bielectrical actions manifested themselves as clear variations of AE activity (responses), the strong responses being observed after second source power up (like to the case of combined action of vibrations and electric impacts). For instance, during alternate EM field sources power-up we have revealed that specimens of terrestrial materials are of high perceptibility to bielectrical action. This was confirmed by control experiments on specimens loaded by constant compression during long period after the session with additional power action at the same load. Above experiments demonstrated the presence of AE responses to repeated bielectrical action (in contrast to acoustic responses degradation tendency in the case of ordinary power action). Moreover, AE responses to bielectrical action were recorded under different values of loads applied to rock specimens (from 70% to 95% of fracture value). This fact once again evidences that abrupt spikes of AE activity during bielectrical actions are nonrandom responses exceeding by amplitude the superposition of responses to EÌ pulses of each generator. It should be noted that the experiments with bielectrical power actions during constant compression session turned out to be useful for understanding the origin of lagged reaction of loaded solids to power impacts produced by solitary source.

Biaxial tests and final analysis.

Biaxial loading by constant stress, in contrast to uniaxial compression, allows recording distinct reaction (namely the response to electric stimulation) of a specimen even under creep test. Experiments were held on the same 100 tons spring press with the help of spring attach for lateral compression, the maximum lateral load being 30 tons. The plots of AE activity obtained for the experiments indicated that action by periodic pulses of moderate voltage (a) as well as high voltage capacitor discharges (b) can stimulate AE growth. In both cases the activation occurs in same delay after start of electric action; the length of delay being near 1000 s in the case (a) but in the case (b) it being less than 100 s. That electric stimulation was powered on when the mean level of AE activity drops after recent stepwise increment of main load at the beginning of measuring session.

The structure of signals of acoustic emission which accompany the inelastic straining of granitic specimens overburden by compressive load and additional power impacts has been studied. The investigation of AE structure based on the waveform analysis are significant to reveal the physical origin of emission pulse. Besides, the results of structural studies are to give essential information about kinetics of fault formation process in a loaded solid. So, for example, the emergence of second spectral maximum of acoustic signal which frequency is lower than that of main maximum implies the microcracking transition from the stage of diffusive accumulation of defects to claster stage of defects growth [4]. Spectra analysis of AE signals was performed. Some modes of spectra were revealed and their dominant frequencies were determined.

The most attractive way to study the transition processes in loaded rocks is to investigate the energy release processes in terms of critical point hypothesis (hypothesis [5] of a simple power-law increase in the cumulative Benioff strain). One should determine the critical parameters of rocks deformation processes distinguishing for this some kind of mechanical characteristics and AE parameters. Obviously such investigations may be useful for detection and description of transition processes in loaded rocks under effect of different physical fields, particularly under vibrations or electrical impacts. It has been determined that avalanche-like mode of AE has a distinctive AE activity curve one can describing by power-law. It was observed, in particular, during the experimental sessions with granodiorite specimens.

Underline.

Resuming lets remark that AE investigation allows to understand the general characteristics of triggered effects in non-steady straining processes in loaded rocks. This is to promote the control of transition and unstable phase of rocks straining up to its fracture or (at least) to predict the forthcoming critical state of the loaded material.

Present research was partially carried out under grant of Russian Basic Research Foundation, project 303-05-65077

References:

1. Nikolaev A.V. Features of Geophysics of XXI century// Problems of Geophysics of XXI century, Moskva., Nauka, 2003, p. 7-16.

2. Bogomolov L.M., Manzhikov B.Ts., Trapeznikov Yu.A. and oth.: Vibroelasticity, acoustic-plastic effect, and acoustic emission of loaded rocks //Russian Geology and Geophysics, 2001, v.42, N10, p. 1678-1689

3. A.Ponomarev, G.Sobolev and A.Koltsov, Acoustic emission under electric excitation, Book of Abstracts, ESC XXVIII General Assembly, Genova, 2002, p.238.

4. Kuksenko V.S. The model of transition from micro- to macrofracturing of solids//In: Physics of strength and plastisity. Leningrad, Nauka, 1986, p. 36-41. (In Russian)

5.Bowman, D., and G. King . Accelerating seismicity and stress accumulation before large earthquakes, J. Geophys. Res. Lett., 2001, No 28(21)}, p. 4039-4042.