Техничке науке / Technical sciences
Приказ монографије / Monograph review

Математичко моделовање побуђених и индукованих потреса у рударству

Mathematical modeling of mining incited and induced quakes

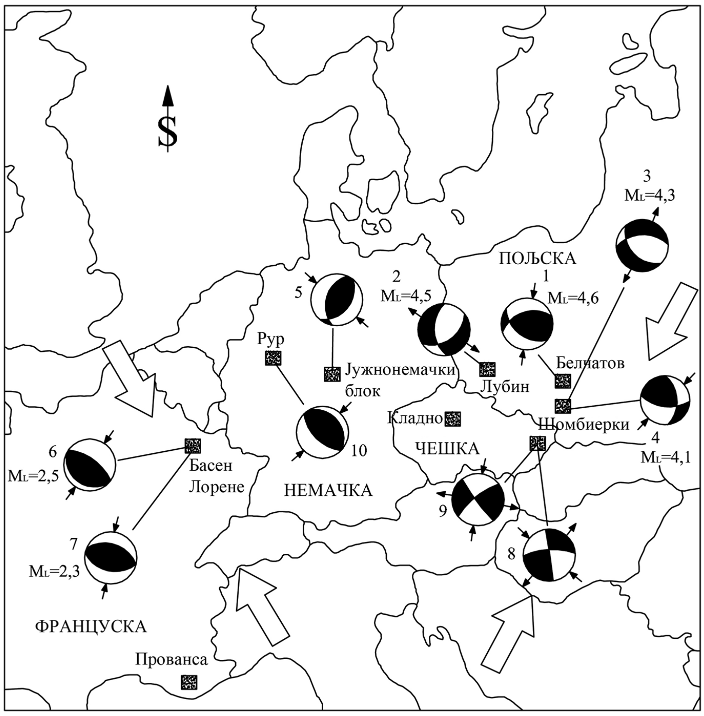
Срђан Д. Костић, научни сарадник
Институт за водопривреду „Јарослав Черни“
Јарослава Черног 80, 11226 Београд
srdjan.kostic@jcerni.co.rs

Srđan D. Kostić, Research Associate
Institute for the Development of Water Resources “Jaroslav Černi”
Jaroslava Černog 80, 11226 Beograd
srdjan.kostic@jcerni.co.rs

In this monograph, the author develops new mathematical models of mining-incited fault motion and blast-induced ground vibration, which provide a comprehensible insight into the background mechanism of fault movement triggered by mining activities, and a reliable prediction of peak ground motion induced by blasting, respectively. The main starting hypotheses of the research were the following: (1) mining incited quakes could occur along the existing fault near the excavation front as a result of intense continuous or transient mining activity, (2) size of blast induced ground motion could be reliably described by complex nonlinear relations among the main blasting parameters and ground motion. As a final outcome of the present analysis, one should be able to determine the role of different technogenic factors on possible triggering of fault motion (and, consequently, mining-incited quakes), and to make reliable predictions of the size of blast-induced ground vibration using derived models.

In order to test the starting hypotheses, two different approaches are used. Effect of different triggering factors on activation of fault motion near the excavation front is analyzed by observing the dynamical changes due to parameter tuning in a spring-block model of fault motion. Blast-induced vibrations are analyzed by correlating among the main blasting parameters and the recorded peak values of ground motion.

Dynamics of fault motion under the impact of the mining-induced external signal, both continuous and transient, is modeled as a corresponding change of parameter and variable values in a spring-block model. A continuous signal is considered to be induced by the work of mining machines, and it is represented by simple harmonic oscillations of parameter values, while short-term signal, which could be ascribed to underground blasting, is modeled as a sinusoidal oscillation of block acceleration scaled by an exponential pulse. The obtained results indicate that the onset of aperiodic irregular oscillations could be controlled by tuning the angular frequencies of parameter oscillations, while the values of oscillation amplitudes are held constant. It should be emphasized that continuous external signal of high frequency, which could be commonly expected in engineering practice, and which simultaneously describes both the friction changes and variations in elastic properties of the rock mass, cannot induce the seismic fault motion. Regarding the impact of the transient external signal, the author examines its effect on fault dynamics in different creep regimes, i.e. within uniform and oscillatory dynamics of spring-block model, which are considered to represent the postseismic and interseismic creep regime of fault motion, respectively. The transient external signal is simulated by a sinusoidal function scaled by an exponential pulse so that the oscillation amplitude envelope has the shape similar to Gauss normal distribution curve. Results obtained indicate that short-term irregular oscillations occur only when dynamics of spring-block model is affected by long-term and low-frequent transient signal. In real conditions, this means that short-term seismic events could occur under the effect of blasting at the exploration front, when the fault is either in post-seismic or interseismic creep regime, provided that the induced changes are long and low-frequent. On the other hand, if induced changes are long and high-frequent, the results of the performed research indicate an occurrence of transient quasiperiodic behavior, which could be interpreted as a convenient model for fault dynamics in a precursory creep regime. This practically means that blasting at exploration face could increase the sensitivity of fault motion on the impact of an external signal, regardless of the current creep regime, provided that the induced changes are long and high-frequent. In this way, the author showed that seismic events could be triggered either by continuous or transient mining activities, i.e. the first starting hypothesis is proved.



Важније појаве побуђених потреса у Европи и њихови типични фокални механизми. Магнитуде забележених потреса изражене су преко локалне магнитуде, M_L, која се дефинише као $M_L = log_{10}A - log_{10}A_0 = log_{10}[A/A_0(\delta)]$, где је A максимална амплитуда осциловања стенске масе забележена Вуд-Андерсоновим сеизмографом, а A_0 представља емпиријску функцију која зависи од епицентралне удаљености од места регистровања (δ).

In order to test the second starting hypothesis, author examines the possible correlation among the main blasting parameters (total amount of explosive for each mining area, total amount of explosive for each delay and distance between the blasting source and recording point) and the recorded values of peak particle velocity for two case studies: quarry "Suva Vrela" near Kosjerić (in western Serbia) and quarry "Drenovac" near Mionica (in central Serbia). Such correlation is established using multilayer feed-forward neural networks with Levenberg-Marquardt learning algorithm. The results obtained indicate that developed models provide reliable prediction accuracy comparable to prediction power of commonly applied conventional predictors, but with a more practical significance of neural network based models, concerning their independence of local natural conditions.

It should be emphasized that present monograph provides sound novelty both from the theoretical and practical viewpoint. Significant theoretical advances are made in the area of dynamics of mining-induced fault motion, by providing conditions for which irregular (stick-slip like) oscillations occur under the effect of continuous and transient changes of parameters and variables, respectively. In terms of the actual fault motion, the results obtained point to qualitative conditions for generation of seismic fault motion, under the influence of vibrations induced by mining machines and blasting at exploration front, at a sufficiently small distance from the reactivated fault.

The main benefit for engineering practice lies in reliability and universality of derived neural network based models for prediction of ground motion induced by blasting in limestone open pits.

Concerning the relevant scientific and practical contributions of the performed research, this monograph is expected to be received well both by the academic and engineering communities.

У овој монографији представљени су резултати истраживања утицаја подземних рударских радова на могућност формирања потреса дуж постојећих раседа у близини чела ископа и карактеристика осциловања стенске масе изазваних минирањима на површинским коповима. Истраживања су обухватила разматрање утицаја транзијентног и континуалног сигнала на динамику модела блока са опругом, као феноменолошког модела раседног кретања, и анализу вршне брзине осциловања стенске масе у функцији главних параметара минирања. Као резултат истраживања, развијени су нови динамички модели раседног кретања, са уведеним континуалним утицајем рада рударских машина и транзијентним утицајем минирања, и нови предикциони модели осциловања стенске масе коришћењем вештачких неуронских мрежа. Аутор је показао да је појава потреса дуж реактивираних раседа у близини чела ископа условљена фреквенцијом континуалног и транзијентног сигнала и дужином трајања транзијентног сигнала. У монографији се указује и на предности примене модела развијених на бази вештачких неуронских мрежа за процену вршне брзине осциловања стенске масе услед минирања у односу на конвенционалне моделе.