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Fracture concentration criterion application to failure nuclei delineation in a rock masses

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In underground mining, a very important safety issue relates to strong dynamic events. It is necessary to develop effective forecasting techniques of their scale and location. The first stage of strong events forecasting is the delineation of dangerous volumes, then in these areas additional analyse should take place. The delineation procedure should be as much as possible formalized and have a minimum of assigned parameters, for objectivity of the obtained results and possibility of its subsequent analysis. The clusters delineation procedure using the kinetic concept of solids strength is proposed.

According to development of the kinetic concept of strength (Zhurkov 1965) using the concentration criterion of fracture (Kuksenko et al. 1975) and the two stage model of fracture (Tomilin & Voinov 1993), the weak events (they have one scale level less than strong ones) must take part in the preparation of the strong ones, which are the result of exceeding the critical threshold concentration of weak events. Therefore, we have only two physical parameters, defining strong event preparation: the size R or energy class K ($\log_{10}R$(m) = 0.33K – 0.4, K = $\log_{10}E$, where E is radiated seismic energy in J) of the seismic event to be for forecasted and the threshold concentration parameter *CP* – a dimensionless value which is the distance between centres of cracks (hypocenters of microseismic events) divided by their mean size. Parameter *CP* characterizes the possibility of an interaction between microseismic events.

The area of failure nucleus was delineated on the basis of the calculation of the concentration parameter for each pair of microseismic events. Then the pairs with *CP* value lower than a given threshold CP_{th}, which have common events, were aggregated in clusters.

All registered microseismic events are regarded as the development of new cracks in

a rock masse, because we have no additional information for a more correct classification.

But to take in account stress relaxation processes and to unlimited decrease of CP only the last recorded events N_{Ev} are used. A second parameter K_{CPmax} is used to avoid a size increase of the concentration parameter when a strong event occurs. All events with energy class larger then K_{CPmax} are considered as events of energy class K_{CPmax}. Last assumption allows avoiding any redundant enlargement of clusters as a result of its association. A natural estimate of the parameter K_{CPmax} is the minimum energy class of a forecasted strong event.

For the experimental examination of the described procedure of clusters delineation the data of microseismic activity in the most rock burst hazardous adit (15-15') of North Ural Bauxite Mine (NUMB) was used. In these site the rock is very brittle. The data contain records of events with energy classes from 1.8 ($10^{1.8}$J) up to 8.6, registered from 1^{st} January of 1984 to 31^{st} December of 1988. The minimum representative energy class for NUMB reliably registered by the microseismic network is K_{min} = 3. As a result, about 1600 events were used for the experimental application.

According to the existing estimates between adjacent ranks of failure (separation to strong and weak), it is possible to forecast the number of events above the 6^{th} energy class on NUMB. The percentage of such events is about 2.8%, i.e. 35 events correspond to strong events, which is higher than the 6^{th} energy class.

The efficiency characteristic of clusters delineation procedure can be on the one hand d_{Strong} – percent of the strong events which have gathered in clusters – and on the other hand the value of its excess d above similar percent d_{Weak} of weak events. The first performance characteristic d_{Strong} defines the maximum value of the probability of the strong event being skipped, its sufficient value is 80-90 %; i.e. it is possible to skip not more then 10-20 % (further it is always more then 90%). The characteristic d denotes the excess of percentage of strong events in the selected data (in clusters), rather than in all analysed events.

The plots of d for $d_{Strong} \geq 90\%$ and different values of K_{CPmax} (events with energy class higher than K_{CPmax} was considered as events with energy class K_{CPmax} when parameter *CP* was calculated) are shown in Figure 1.

Analysis of the data for K_{CPmax} = 6 and different CP_{th} and N_{Ev} shows that the excess of percentage of strong events (energy classes higher than the 6^{th}) in clusters above all other events in cluster (weak events) for $d_{Strong} \geq 90\%$ is up to 31 %, i.e. in clusters of strong events was select on 31 % more than weak ones. If events with energy class larger than 6.5 are considered, then it was select already on 38 %

more than events of smaller classes. At the same time, events considered in the 5 till 6 energy classes, which can also be considered rather strong, but not being a subject of this prediction, are selected only on 15% more than the other. Thus, the value of the probability that an event turns up in a cluster grows with growth of its energy class. For events up to class 6 such tendency can be bound with the decrease of parameter CP, with the growth of the crack size, which leads to an increase of the probability of it coming in a cluster.

It is possible to remove the described effect for examination of this assumption by reducing K_{CPmax}. According to the obtained results when K_{CPmax} = 5 the detected relation remains, but the maximum of d is down to 25%. An extreme case occurs when K_{CPmax} = 3, i.e. all events have the same energy class equal 10^3J. It is equivalent to clusters delineation procedures on the basis of events concentration consideration. The results of its application have least efficiency, as maximum d is equal to 13%.

The best efficiency (maximum d) is reached when clusters are delineated from a sample volume N_{Ev} = 175 events and considering a concentration parameter *CP* = 10, which is consistent with value of *CP* obtained during the investigation of earthquakes in Kamchatka.

It is interesting to find out the behaviour of characteristic d in time. It shows that d is always larger than 19% and presents no significant changes from one time sample to another. Such behaviour allows suspecting an opportunity of good set-up of parameters of a clusters delineation procedure for forecasting strong seismic events in mines and other underground objects.