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DIMENSION OF UNDERGROUND MACROSEISMIC EFFECT AREAS CAUSED BY ROCKBURSTS IN OSTRAVA–KARVINÁ COAL BASIN

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Abstract. In view of mining workers, the macroseismic effects of seismic events caused by mining activities affecting underground workings are an important criterion for their underground labour safety. Macroseismic effects depend on many factors relating to the seismic event itself, on properties of its surroundings and on driving the underground working itself.

Limit distances of possible effects caused by seismic events, depending on the energy radiated from an event, were carried out on the basis of processing all the seismic events with macroseismic effects (microrockbursts and rockbursts) from the Karvina's part of the Ostrava–Karvina Coal Basin (OKCB) for the period of 1980–1996.

For the limit radius of area with significant floor rising (0.2 – 0.5 m) depending on energy of seismic event, the following empirical equation was found

$$\log r = 0.1697 \log(E) + 0.7696$$

and for the most probable radius of the area affected by macroseismic effects another equation was found

$$\log r = 0.1695 \log(E) + 0.8269\,.$$

1. Introduction

All the seismic monitoring jobs are thought to enhance the safety of underground labour. They represent one of the methods helping to determine the way and scope of passive and active protection against rockbursts. Macroseismic effects depend on various parameters of the particular seismic event (i.e. energy and its radiation, focal localization, focal dimensions, focal mechanism, drop of stress within the focus, focal positioning and shifting in relation to underground working), on the properties of the surroundings (stratification, amplitude attenuation of seismic waves depending on distance, strength) and on the properties of the particular underground working (system of driving, system of reinforcement, location towards the coal seam, overlying and underlying strata of the coal seam.

To find out maximum distances at which the seismic events have macroseismic effects upon underground workings, all rockbursts and microseismic events registered from 1980 in books of registered rockbursts introduced at the CSA, Doubrava, Darkov and Lazy collieries were processed. Only the events with determined energies and with fully described consequences were included into the system of processing. The limit distances, at which the slip of TH reinforcement still takes place and the floor or possibly the roadway and the coal face get totally blocked, were analyzed as well. Attenuations of macroseismic effects, depending on distances and the diameter of affected area, were monitored too.

2. Theoretical Starting Points

Energy in the OKCB is calculated from voluminous P and S waves, i.e. as the integral of a squared amplitude of the velocity from the first motion of P wave for period of 1.5 s when namely reflected S waves do not appear in the waveform yet [Sglunda et al. 1987; Slavík 1992]. The energy calculated in this manner was bound up with energies which had been calculated till 1985 from photoregistrations and triggered ELSMO seismometers [Holub et al. 1985].

The energy scale has remained stable since 1980 when first seismologic stations with photoregistration began to operate up to now when completely new seismologic network with the UGA instrumentation sets are already in full operation in the eastern part of the OKCB. However, the energies determined according to this scale do not correspond with those determined, for example, at Polish coal mines and in the energy range of 10^4 J they are nearly by one order lower.

Since 1989 the relative accuracy in determination of energies in the OKCB has been approx. 1/3 of order [Kalenda 1992].

The size of a focus and its orientation relating to underground working has a principal impact upon microseismic events. The following empirical equation between the thickness of a cracking layer (strata) and the seismic energy relieved was derived for the stratified environment of the OKCB [Kalenda 1992]

$$\log E_{\max} = 4.29 \log h - 0.56\,, \qquad (1)$$

where $E_{\max}$ is the limit energy for the thickness of h layer.

The length of focus is usually 3 – 5 times greater than its size and it is bound with the thickness of a layer.

According to seismological measurements the factor indicating the amplitude attenuation in oscillation speed of a mass particle by distance varies from 3.2 to 3.4 [Kalenda 1992].

Based on detailed seimoacoustic parameter measurements and seismic radiation through the coal seam the factor showing the amplitude attenuation of acceleration was determined between 2.5 – 3.2.

Direction of the waves incoming towards the underground working and their polarization have also an impact upon the magnitude of macroseismic events. The greatest effects are caused by S waves in the direction perpendicular to that of a ray. The situation is more complicated in the case of seam rockbursts when channel waves are generated in the coal seam, the amplitude of which exceeds the amplitudes of body P and S waves by one order.

It is evident from the equation (1) that the hypocentral distance of a focus from the underground working within "near zone" is comparable with the size of a focus and above all it depends on the position of S.S. focus and its orientation towards the underground working. Macroseismic events behind the "near zone" depend above all on the attenuation of energy by distance. The energy should approximately decrease with the sixth power of distance. The largest size of the affected area depends namely on the attenuation of energy with the distance but the mean distance of effects depends namely on the dimensions of the "near zone" and its orientation towards the underground working.

3. PROCESSED DATA AND RESULTS

Altogether 85 seismic events were processed. Energy–frequency distribution and classification of events according to coal mines are displayed in Fig. 1. The greatest number of events with consequences were observed in the energy range 10^4–10^7 J. Only 6 events (7 % of all events) with consequences observed had energies below 10^4 J although the number of small seismic events below 10^4 J is more than 10 times greater than number of greater events with energy over 10^4 J. The consequences resulting from these small events were observed in a very limited area and this was mostly the question of floor rising up to 0.7 m in maximum (mostly 0.2 – 0.5 m) or coal was discharged from the opening.

47 events were processed at the CSA colliery, 24 events at Doubrava colliery, 11 events at Darkov colliery and only 3 rockbursts came from Lazy colliery. The rockbursts covered almost regularly the entire period processed from 1/1/1980 to 1/7/1995 and the growth in occurrence of events with maximum energies in 1983 was connected with the extraction of the 3rd block at the CSA colliery (see Fig. 2).

The following data were searched for from the books for registration of rockbursts:

- total diameter of affected area where floor rose above 0.2 metre or the reinforcement was apparently deformed or destroyed
- area diameter where floor rose no higher than 0.2 m
- area diameter where floor rose no higher than 0.5 m
- area diameter where floor rose above 0.5 m
- area diameter where slide of TH reinforcement was up to 5 cm
- area diameter where slide of TH reinforcement was up to 20 cm
- area diameter where slide of TH reinforcement was above 20 cm
- maximum deformation and slide
- maximum floor rising or coal discharging.

Fig. 3 shows the values of TH reinforcement slides found which are classified into the above indicated categories and Fig. 4 shows the values of floor rising in corridors. The straight lines indicating the dependence of diameter of affected area on energy were inset for each category by method of the least squares according to this equation

$$\log r = k \log(E) + g, \quad (2)$$

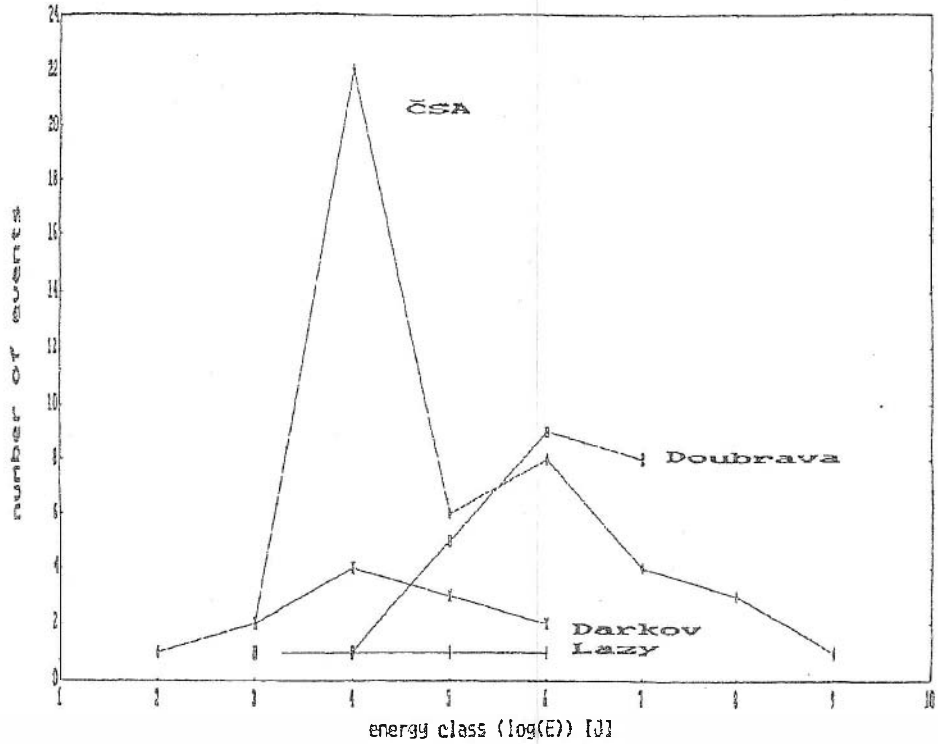

FIG. 1. Energy–frequency distribution of seismic events in individual mines

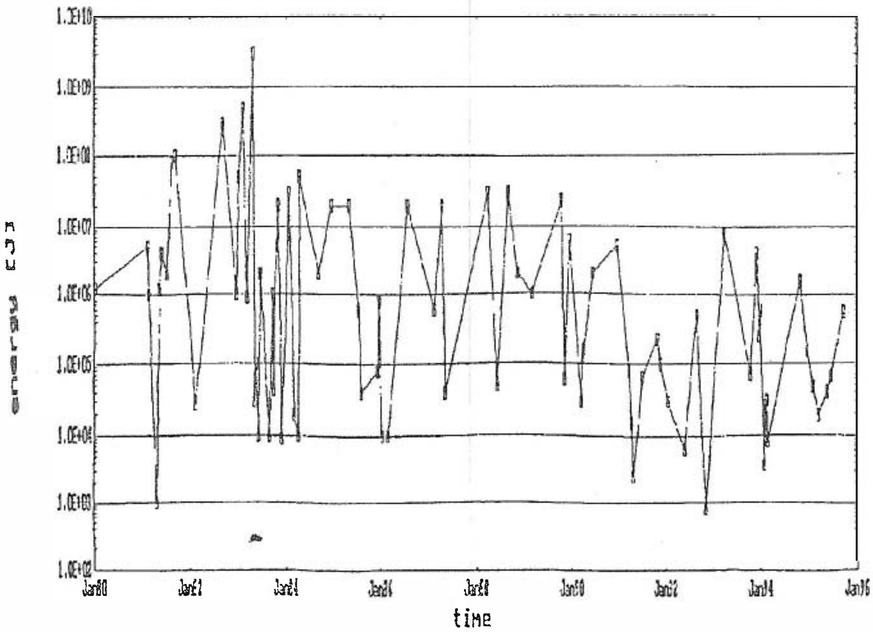

FIG. 2. Time sequency of processed rockburst

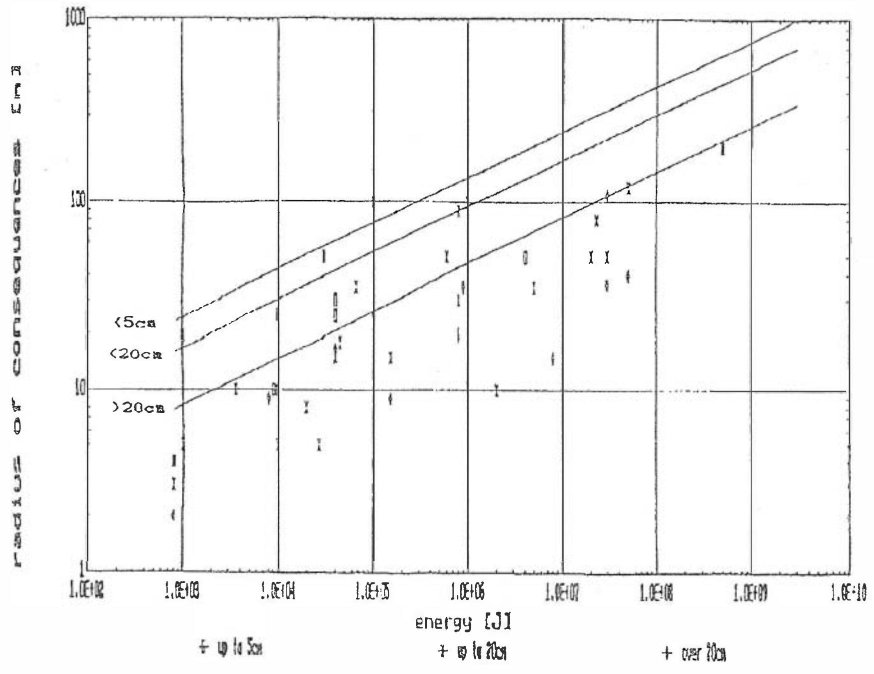

FIG. 3. Slips of TH reinforcement

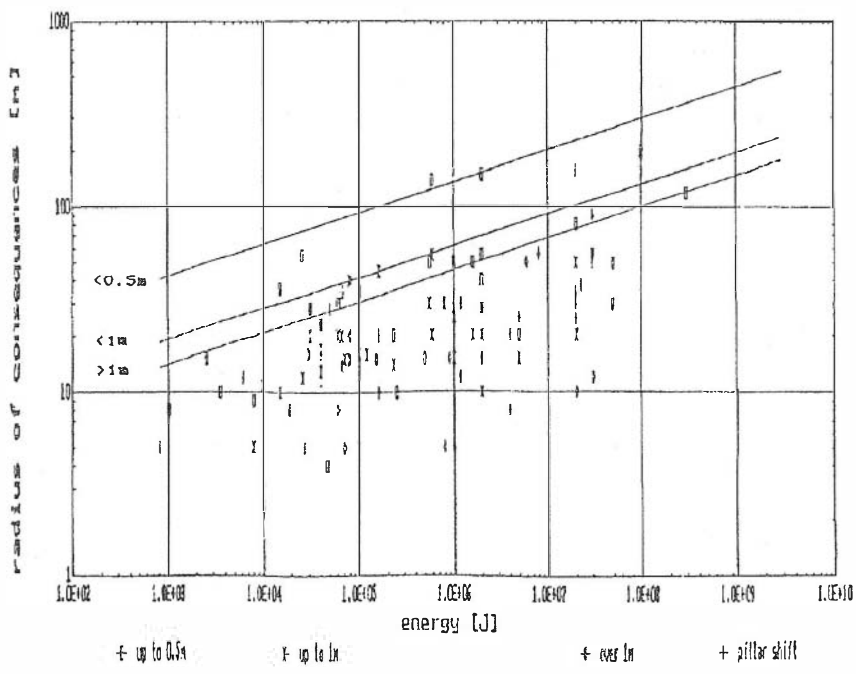

FIG. 4. Floor rising

where r [m] is the diameter of an affected area and E [J] represents energy. Mean values of the k gradient according to equation (2) and towards the middle of individual categories were inset with mean dependence of area diameters on energy.

Limit straight lines were inset with maximum values (two at least) representing maximum distance in which given consequences will still take place at given energy. The results are presented in Table 1, where Qty is number of cases, k is slope of attenuation of diameter of affected area with energy by equation (2), q is absolute parameter in equation (2), k_{med} is the mean values of parameter k for whole set of TH reinforcement slides or floor rising. Parameter q_{med} is mean parameter for individual TH reinforcement slides and floor rising calculated for mean slope parameter q_{med}. Parameter q_{max} is upper limit of individual TH reinforcement slides and floor rising sets, calculated for mean slope parameter q_{med}.

TABLE 1.

	Slides of TH reinforc.			Floor Rising			Area
	to 5 cm	to 20 cm	abv 20 cm	to 20 cm	to 50 cm	abv 50 cm	Diameter
Qty	11	20	12	31	33	14	84
k	0.2353	0.2768	0.2371	0.1981	0.1001	0.2108	0.1993
q	0.3341	−0.1589	−0.0811	0.4053	0.7266	−0.9953	0.8269
k_{med}		0.2497			0.1697	0.1589	0.1993
q_{med}	0.2849	0.0006	−0.1327	0.5831	0.3565	0.1745	0.6094
q_{max}	0.6378	0.4806	0.1695	1.1167	0.7696	0.6383	1.1308

All found values of the maximum diameter of an affected area, where floor rose above 0.2 m or where reinforcement was evidently deformed or destroyed, are plotted in Fig. 5. The dependence of limit and mean diameters of the area on energy are plotted similarly as it was in cases of TH reinforcement slides and floor rising. The most probable dependence of the diameter was calculated on the basis of a median of deflections from the dependence of the mean diameter of the area on energy.

It is evident from the TH reinforcement slides in Table 1 that the dependence gradient of an area radius on the energy of an event is greater than that of floor rising and this gradient approximately corresponds with the fourth power of energy decreasing by distance. On the other hand, it seems from the floor rising that the mean dependence gradient of the area radius on energy corresponds approx. with the sixth power of energy decreasing by distance. The dependence gradient of the affected area diameter on energy corresponds approx. with the fifth power of energy decreasing by distance.

Because the radius of a focus grows approx. with the fourth power (see equation (1)) then probably the size of the focus was applied stronger than the energy decreasing by distance (as for the slides appearing in shorter distances, comparing

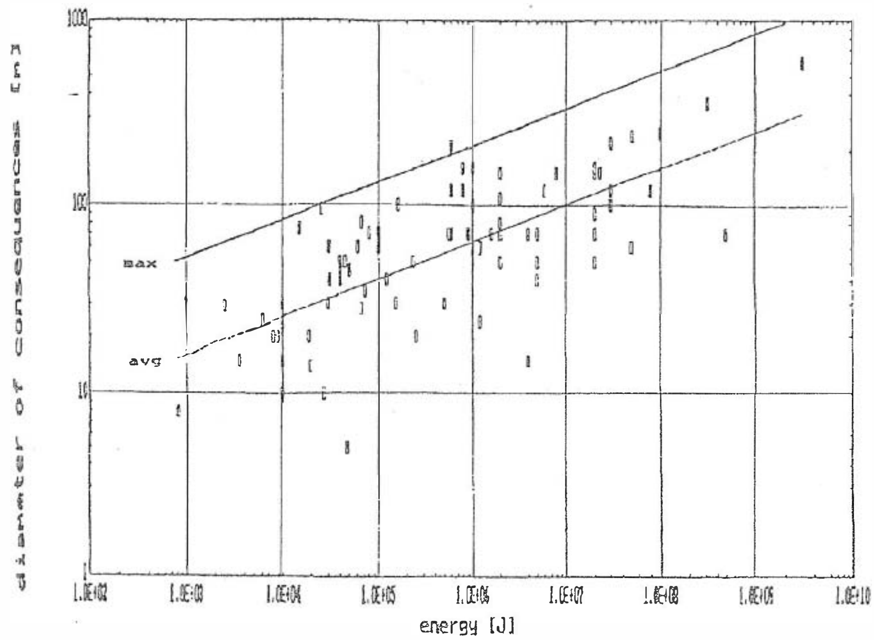

FIG. 5. Dimension of macroseismic effect areas

with more distant floor rising). On the other hand, the amplitude attenuation of acceleration by distance is already evident from floor rising.

The dispersion of gradients for the slides of TH reinforcement is lower than the dispersion of gradients for floor rising and this may be connected with the appropriate extracting conditions and greater data homogeneity of the slides, the mechanism of which is not so dependent on other effects.

4. CONCLUSION

Empirical dependencies of area radii of macroseismic effects affecting underground workings on the energy from seismic events were derived from data received from 85 underground rockbursts and microrockbursts having occurred in the OKCB in 1980 – 1995. The determined dependencies show that the energy for the slides of TH reinforcement increases with the fourth power of distance which corresponds with the radius size of a focus. The dependence of the area radius of floor rising corresponds with the attenuation of seismic waves by distance.

To find out the most probable diameter of the area affected with macroseismic events the following equation was derived :

$$\log d = 0.1695 \log(E) + 0.8269 .$$

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