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HYDRAULIC FRACTURING TECHNOLOGY IN ROCK BURST HAZARD CONTROLLING

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Abstract: All methods of rock burst hazard evaluation and control are classified as rock burst prevention. The prevention methods can be divided in two general categories – the passive (non-active) and active ones. Active methods of rock burst prevention focus generally on reducing of stress level in the area of its concentration through controlled tremors and rock bursts by blasting works.
Among the active methods the hydraulic fracturing can be noted. Traditional hydraulic fracturing techniques generally form main hydraulic cracks. However, when we combine hydraulic fracturing with blasting we might obtain much better results. For example, the hydraulic crack range becomes wider than by using only conventional methods. In coal seams it is possible to increase permeability which makes gas drainage to be more effective. It is because water shockwaves and bubble pulsations induced by the explosion, cause a high strain rate in the rock mass surrounding the bore hole.
When hydraulic fracturing is used, a micro seismic event takes place. This is why micro seismic technologies are used to monitor the range of hydraulic fracturing process.
This article is only mentioning the issue which in the Author opinion, deserves more attention.

Keywords: underground mining, rock burst, crump prevention, hydraulic fracturing

1. INTRODUCTION

Since the moment, when the single excavation has been made in rock mass, the original stress/strain equilibrium state is more or less disturbed. When the mine operations are deeper and deeper and the rocks are stronger and stronger, the greater amount of strain energy is accumulated within the adjacent rocks. When this energy is permitted to release violently, it may take a form seismic event called rock burst (or

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crump). Along decades, the mining industry has collected the data and conducted research, which made possible the rock burst phenomenon better recognition. But in spite of everything what has been already acquired in this topic, the rock burst hazard hasn’t been entirely identified and still it is the biggest threat in underground mining, especially when it takes place along with high potential for the methane or coal dust explosion.

In Poland the rock bursts hazard occurs in both coal and copper underground mines. According to article (Patyńska and Kabiesz, 2014) in 2011-2012, 22 out of 30 mines at the Upper Silesia Coal Basin were mining from crump-risk seams and the amount of coal produced in those 22 mines was covering about 47.5% of total national production. Therefore it is a matter of high priority to evaluate crump risk accurately and enter appropriate prevention measures.

2. ROCK BURST PREVENTION

In 1950-1960 at the Upper Silesia Coal Basin, there have been yearly recorded about 300 rock bursts having their origin in relatively weak seam of hard coal. In a long time, after enforcing preventing measures, the number of those events decreased to few per year. The other area where rock bursts are recorded and prevention is proceeded is Legnica-Głogów Copper Basin (rock burst hazard has its origin in high strength of rock within the main roof strata (Kidybiński, 2003).

Reducing the possible rock burst consequences and the possibility of rock burst occurrence itself, are the main goals of crump preventing activities. In general prevention procedure, one should take into consideration three different approaches simultaneously, i.e. technological, technical and organizational approaches (Table 1).

Widely understood rock burst prevention include the methods which permit (a) identifying of hazard level and (b) rock burst controlling. It concerns almost the whole production process, from mine workings planning through exploitation to handling the caved zones.

Well planned preventing measures should include such consideration stages as: finding the causes and sources of rock burst hazard, control methods selection, enforcing prevention methods and verifying their effectiveness (Butra and Kudełko, 2011).

Table 1. Methods of rock bursts prevention (Butra and Kudełko, 2011, modified)

Technological	Active	Organizational
Sequence and direction of mining	Group winning blasting	Personnel training
Pattern of mining system	Winning and release blasting in solid	Organization of rock mechanic services
Roof control method	Release blasting in floor	Analyzes of hazard level
Working support	Release blasting in roof	Establishing zones of special rock burst hazard level
Clean mining without leaving rests	Hydraulic fracturing of roof (or seam*)	Waiting time period
Discontinuation of mining	Watering of rock-mass	Personnel minimizing

*added by Author

2.1. NON-ACTIVE ROCK BURST PREVENTION

The basic requirement in maintaining the rock burst hazard on an appropriate level is ensuring the adequate management in mine. Basically it covers proper mine designing, planning its levels and floors and controlling mine works so the areas of stress concentration would not be created and not to allow stability loss (Goszcz, 1999). Those are standard actions commonly taken simultaneously in underground mines, and they do not require additional investments.

In Polish metal mining rock bolts are successfully used as one of the non-active rock burst prevention methods. As contrary to metal mines in coal mining often the role of rock bolts is underestimated in reducing the risk of roof failure. It is advised to change generally support system in coal mines from steel arches to rock bolts which proved to be successful in the USA and France by preventing accidents caused by rock bursts and roof falls (Kidybiński, 2003).

2.2. ACTIVE ROCK BURST PREVENTION

Active methods lies in inducing the rock-mass tremors. For example tremor and winning blasting of faces can be used, also blasting explosives in additional holes which are longer and wider than the boreholes used for faces blastings. In room-and-pillar mining systems, release blastings are used to prevent stress concentrations (Butra and Kudełko, 2011).

Among methods of reducing rock burst hazard those less expensive (mainly non-active methods) are usually preferred. It is advised to apply new technologies of roof strata engineering and directional hydraulic fracturing more widely (Kidybiński, 2003).

One of the main difficulties in winning blasting and plain hydraulic fracturing is their low effectiveness and failure. About 0.2÷0.5 MPa pressure is obtained in blasting while water fracturing indicates pressure about ten times bigger, but only combining those two techniques is able to bring measurable effects (Krawiec, 2005).

Reducing the rock burst hazard by active methods is taken under consideration when it is not possible or insufficient to apply other – non-active methods.

3. HYDRAULIC FRACTURING TECHNOLOGY

The method has been developed in 1947 but it waited almost a half of a century to be tested. As an effective measure it has been widely used for exploiting of low penetrating oil and gas pool. In 1960s Soviet Union carried tests of hydraulic fracturing in underground coal mine (Xu et al., 2011).

Hydraulic fracturing is formed by tensile crack inducing. On the other hand, the shear type mechanisms were observed in most of the acoustic emission events recorded during the laboratory and field hydraulic fracturing experiments (Shimizu et al., 2011).

The structure of coal and rock mass can be broken with hydraulic fracturing, which can improve coal permeability and weaken rock strength to minimize rock bursting ability. This requires hydraulic fracturing produce hydraulic cracks at great range. Combined methods of hydraulic fracturing and controlled blasting gives us water pressure blasting which can effectively control the generation of blasting flying rocks, air shockwaves, blasting tremors, and detonation of toxic gases. Water pressure control blasting induces hydraulic fracturing in the borehole of a coal/rock seam, which changes the structure of the coal/rock mass and increases the number and range of hydraulic cracks. This technology may be implemented by following steps (Huang et al., 2011):

a) Drilling a borehole for hydraulic fracturing and injecting the water-proof gel/emulsion mine explosive.
b) Sealing up the borehole with cement and injecting water until it reaches the adequate pressure value.
c) Detonating the explosives to initiate water pressure blasting which will cause high strain area surrounding the borehole. While the stress exceeds the rock will rapture and create radial fractures which are extended 3-5 times borehole diameter.
d) Conducting water injection, pulse or cycle injection to carry on hydraulic fracturing.

On Fig. 1 schemes of the borehole and its vicinity before and after hole blasting are presented.

In the process of fracturing, each fracturing reinjection will certainly give rise to tensile stress at the normal direction of the weak plane. We can assume that the water pressure inside the borehole is theoretically infinitely high (practically – very high) at the moment of the blast, and pressure that high could not be reached using only hydraulic fracturing without blasting.

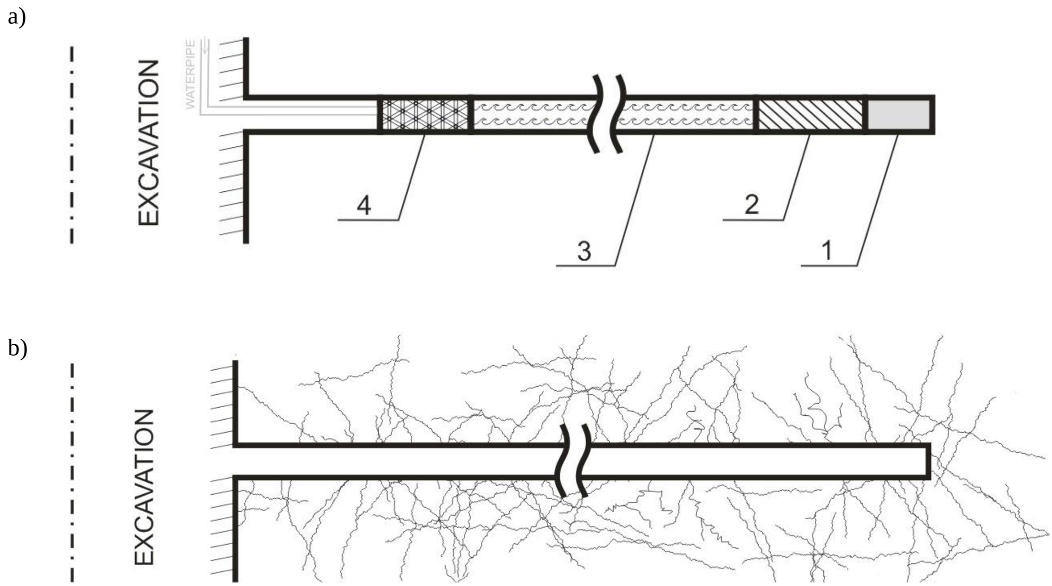

Fig. 1. Water pressure blasting borehole scheme (based on Krawiec, 2005): a) situation before blasting; b) situation after blasting; 1 – primer (detonator and booster), 2 – explosives, 3 – water under pressure, 4 – stemming (solid)

When running hydraulic fracturing, once the water pressure exceeds rock strength, cracks generate, and then micro seismic event occurs. Locating the positions of those events using monitoring will give us the knowledge of the cracking range dynamically, and rate the effect of hydraulic fracturing. But before monitoring the hydraulic fracturing range by using micro seismic techniques, water injection must be stopped for a time till the original fracture is closed, when monitoring is in progress, the injection of water should run. In order of that closed fractures will reopen under hydraulic pressure, and trigger many new fractures followed by many micro seismic signals. Such activities will help finding hydraulic fracturing range (Qin et al., 2012).

It is known that process of hydraulic fracturing can be manipulated by changing the viscosity of fluids injected into borehole (Shimizu et al., 2011), by controlling the water pressure and adding blasting (Huang et al., 2011).

The results ran under different pressures show that single-drill hole fracturing radius rise to 6 m under the pressure of 27 MPa, which is 3÷5 times more than under pressure of 14 MPa (Xu et al., 2011).

4. SUMMARY

Seismic activity and rock bursts are very common in today's underground mining where high strain takes place. And when a high stress resistance of rocks combines with a high stress, dynamic phenomena such as rock bursts occurs. Happily those events can be predicted, evaluated and prevented when appropriate actions will be undertaken.

Rock bursts preventing measures in underground mines are based on actual hazard level evaluation so it is very important to develop new approaches in evaluating such as new algorithms and mathematical models so the results of the evaluation would be more accurate and detailed. Rock burst hazard will probably increase in the future due to mining on the bigger depth. Despite of many achievements and solutions on rock burst prevention, the intensification of research aimed on this issue is necessary.

The cooperation between blasting and hydraulic fracturing is also in deep need of further research. With theoretical calculations and modeling, with taking fluid viscosity and pressure under consideration and improvement in technical and monitoring equipment, hydraulic fracturing may become an almost perfect tool in rock burst prevention methods. This technique can induce fracture extension and development, expand the range of hydro fracture and improve the gas drainage (for example methane in coal-beds).

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