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FUNDAMENTALS OF A PRACTICAL CLASSIFICATION OF MINING INDUCED SEISMICITY (ROCK BURST)

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ABSTRACT

The most important prerequisite for the effective investigation and control of the seismicity in and around mines is the knowledge of the mechanics of the complete rock burst processes. The literature and case studies of rock bursts show that there is no accordance in relation to the fundamental source mechanism and to the definition of the rock burst phenomena in general. So, it is difficult to generalize the results of rock burst mechanism investigations from different mining areas.

Therefore, the Economic Commission for Europe (Coal Committee) of UNO is going to develope a new definition of the phenomena "rock burst" and "mining-induced seismic event" as well as an international classification of rock bursts (1994). The new criteria for the classification should be the features of the fracture mechanism within the source and the mechanism of energy emission in opposite to the former classification which has been related to the effects and damages in mining openings, mainly. The new classification would not more exclude e.g. the so called "bumps", i.e. the seismic events in mining areas without damages in the underground

workings itself. Besides other advantages for the safety of mining technology the classification should be in clother relation to the common rock mechanical and seismological mechanism of induced seismic events in general.

A proposal for the fundamentals of this classification will be presented and discussed. This is also a call to scientists and engineers in earthquake engineering and mining sciences to share by own investigations of rock bursts mechanism to a practicable classification assisting the seismicity investigations in mining areas as well as the mining safety, too.

INTRODUCTION

In October 2-6, 1989 in Ostrava/Czechoslovakia took place an international "Symposium on Forecasting and Prevention of Rock Bursts and Sudden Outbursts of Coal, Rock and Gas" initiated by the Coal Committee of the UNO-Economic Commission for Europe (ECE). In the overall conclusions of the official report of the meeting /1/ was established:

"Participants identified the following factors as impeding a fuller control of rock bursts and sudden outbursts:

...

(c) intentionally: a certain confusion as to the exact meaning/definitions of terms, classifications, parameters, etc. used in the various countries. This lack of accuracy impeded the international exchange of data, the common analysis of bursts/outbursts (case histories), ..."
(/1/, point 40, page 10)

and

"with a view to enhancing international co-operation, participants appealed to the ECE Coal Committee:

...

(b) to establish an ad hoc meeting of experts with the mandate to develop an ECE classification of rock bursts/sudden outbursts in underground mines, including related issues such as terminology, measuring devices and standards. Such a classification would be a first step in overcoming present obstacles in the international exchange of data, analysis of incidents, comparison of performance of devices/appliances, and national regulations and norms. The classification could become a contribution of the Coal Committee to the United Nations International Decade for the Prevention of Natural Disasters (1990s). International governmental and non-governmental organizations dealing with mining, geomechanics, seismology, geology should be invited to contribute, so as to secure a comparable data flow between disciplines."
(/1/, point 44, page 11)

This shows clearly the actual situation in the field of rock burst investigation:

Despite of remarkable advantages in combating the rock burst danger in single mining districts the rock-mechanical and seimological mechanism of the phenomenon "rock burst" is not clarified enough to understand the different manifestations of rock bursts under different mining and geological conditions. On the other hand this is the prerequisite to develope efficient strategies for fighting against rock bursts. The following paper will give an impression on the existing problems and discuss some proposals for clasification and definition of rock bursts.

STATE OF THE ART IN ROCK BURST CLASSIFICATION

Rock bursts ever has been very severe injuries in mines and the first and most common attempts to define and classify this phenomenon started therefore from the damaging effects within the mines. As "rock bursts" often only these events was classified which gave rise to damages in the mine workings. In this sense e.g. Bräuner /5/ defined the rock burst as "a fracture by which the coal breaks into the mine working with an explosion-like force" or later in an other publication/6/ he defined the "rock burst in a more narrow sense as a shock-like fracture the energy of which comes from the elasticity of the rock masses". He separated the rock bursts from the "mining earth tremors" caused by mining and shaking the mine and the surface but not damaging the mine workings /6/.

This separation, supported by a lot of other mining engineers, expresses the most serious problem of the classical rock bursts definitions and raises the questions: Is the emission of energy by brittle fracturing of rocks and sources situated far from an mining opening and connected or not connected with damages in the mine working also a rock burst or not? What is the limit in relation to the distance of the primary sources from the mine working? What about the brittle fracture of a residual pillar in the goaf of a mine in several hundred meters distance from the active stope connected with a big energy emission but without damages in the active workings? Is that a rock burst or not ?

Gibowicz /7/ divided between tremors and rock bursts and said "there are tremors causing rock bursts and tremors causing not rock bursts" but tremors are mining-induced seismic events."Rock bursts are a small subset within a large set of mining-induced seismic events"/7/. That means that a definition and classification of rock bursts would deal only with one small part of effects of brittle fracture processes in mines and these effects are only partially determinated by the fracture process itself but also (and in some cases very clearly) by the technical conditions in the mine (support, bolting, mine design etc.), by technological conditions (absence of men in the stope, room and pillar mining methods etc.) or by the technological "history" of the opening (e.g. state of the contour strength) and so on.

If we include only a small "subset" of all mining-induced brittle fracture processes in and around the mine in the investigation of rock bursts we are unable to discover the whole process "rock burst", its preconditions, the interaction of technological and natural conditions and last but not least the real mechanism of the origin of rock bursts damages in the mine.

Starting with the papers of Knoll /8,9/ and the following papers / 10,11/ the weight has been more concentrated not to rock burst in the former narrow sense but to the complex phenomenon "brittle fracturing of rocks in and around mines and caused by mining" as a complex induced fracture process including the effects underground and at the surface.

On this base further proposals for a more complex definition of rock burst were given by Konecny /13/, Ryder /14/, Semjakin /15/, Johnston /16/. The authors understand the rock burst as a mining-induced seismic event and discriminate two main types, one having the source near to the mining openings and the other one far from it.

The two main types can occure in different variations depending on natural (geological, tectonical, rock-mechanical) conditions. And the damages in the mine are consequences of the rock bursts determined by technical, technological and, of course, geological conditions.

Under "induced seismic event" they understand (like earthquakes as natural, tectonic seismic events) the source process (focal fracture mechanism), the radiation of energy (seismic effect), the effect of seismic waves (dynamic loading) on a site (underground or at the surface, respectively).

FUNDAMENTALS OF A NEW DEFINITION AND CLASSIFICATION

The first question to be answered is the question for the aim of a new definition and classification of rock bursts in the general sense. In mines there are two main fields of interest:

i) The interest to have a definition and a classification to describe and classify the effects in the mine, i.e. a tool for safety statistics and for communications with mining safety authorities. This is important for the evaluation of the development of the safety in the mine and to decide appropriate measures for fighting against damages.

ii) The interest to have a definition and classification as a tool to be able to evaluate the interaction of minig technology and natural geological and tectonical conditions with respect to the origin of mining-induced seismic events and the developement of a potential for damaging effects within the mining workings and/or the surface above the mine.

The first point contains a definition and classification more for the dayly mining practice in certain districts. The regulations depend on the local conditions and the specific mining technology and agree - as a rule - with other regulations and definitions in the mine. The miners does not want to change this system of regulations and definitions. But the definitions and classifications on this base are local ones and not compatible with the corresponding definitions in other mining districts.

Therefore most of results of statistical and technical investigations, some measures for forecasting, combating and fighting against rock bursts are not comparable with corresponding topics in other mining regions.

Another point is the growing knowledge about the mechanism of rock bursts. From case studies in a lot of mines is well known, that for several "rock bursts" the focal zone of the primary brittle fracture process and the site of damages within the mine are more or less distant. Several hundred meters or single kilometers has been observed as distances, particularly in the very well investigated deep gold mines of South Africa /14, 17/, in Ostrava-Karvina district /18/, in the Tkibuli-Shaor deposite /19/ and in other regions. It is impossible, especially in the above named cases, to understand the whole process of preparation, fracture, energy exchange as well as place and extension of damage of the "rock burst phenomenon" if as a "rock burst" are considered only fractures of the immediat contour zones of mining openings.

In the same sense, if one only considered the site of damages, even prevention measures cannot were directed to the primary reasons of the burst and so they cannot be effective from the very start in some cases. Particularly, one cannot fight successful against even the very powerful rock bursts showing a complex and more-component fracture mechanism if one is going out form a single opening or mine working but not from the large scale interaction of the mine with the "geological environment" in a region extended in the order of several times of the extension of the whole mine.

In the conclusions of the last ECE-syposium /1/ one can find:

"20. It was clear from the discussion that while recognizing the achieved progress in understanding the circumstances and causes of rock bursts as well as of their forecasting and prevention, further research in this field should continue on a larger scale on national and international levels. This related particularly to the research on: measurement methods and techniques, modelling techniques, and simulation methods applied on local and regional scale.

21. For the common benefit of the mining industry of the ECE member countries, the basic research on these phenomena could be co-ordinated so as to direct the scientific efforts on subjects of priority to the safety of mines. Among others, such activities should focus on the following problems:

- basic theoretical research on the rock burst occurrence,

- uniform terminology and classification of rock bursts occurrence and rock burst mechanics,

- rock burst occurrence in seismic regions as well as in regions with induced seismicity and its relationship,

- evaluation of rock burst energy balance and its classification

...

- setting up regional measures for preventing and forecasting rock bursts ... during the design, construction and exploitation of mines,

- geodynamic surveying of coal fields".

To fulfil this clear tasks, it is to develope even a rock burst definition and classification in the second above mentioned field of interest, containing

- the whole and complex rock burst process,
- in the first order not local but regional and general features,
- generalisations, permitting the use of the results to all local mining conditions.

The definition and classification must therefore have a "generalized model character" and must give the joint base for local site-related measures and regulations. So, the definition and classification can help the researchers to develope the modelling of the rock burst process, the engineers to carry out and compare case studies and methods for forecasting, prevention and limitation as well as can help to develope countermeasures really directed to the primary reasons of the fracture processes and to find the possible places of effecting the mine (and the surface).

DRAFT PROPOSALS FOR A NEW DEFINITION AND CLASSIFICATION

The following proposals are given for a new definition and classification corresponding with the above summarized fundamentals and with the task of the ECE-symposium /1/:

Definition (Fig. 1):

1. Rock bursts are mining-induced seismic events.

2. Mining-induced seismic events are sudden, brittle fractures of parts of the rock mass within the range of the mining-induced stress redistribution and connected with emission of deformation energy stored in the rock mass, which is influenced by mining stress redistribution.

3. The sources of stored and emitted energy are
   - the tectonic stress field and
   - the gravitational stress field and
   - the immediately mining-induced stress field and/or
   - the mediately mining-induced stress field.

   The immediately mining-induced stress field is the stress field induced by mineral extraction and changing of geometrical structure in a mine (underground and/or at the surface: e.g. by shafts, openings, stopes, roadways, open-pits, bunkers, pillars, insulas within the goaf etc.). The immediately mining-induced stress field occure, as a rule, in different scales: in the contour zones of openings (roof, bottom, seam edge etc.) and in bigger dimensions and distances from the openings within the rock mass.

   The mediately mining-induced stress field are the stresses caused by technogenous sinking or rising of ground water level, weight changes by reditributions of large masses, destressing of water, gas or oil accumulations, injection or extractions of liquids within the influence region of the mine, inducing of large scale deformation fields around mine etc.

4. Depending on the position of the primary fracture zone (primary focal zone) and the real natural and technical conditions the mining-induced seismic events can result in local destructions within the mining openings or at the surface.

Rock burst process (Fig. 2):

Corresponding to the definition given above a mining-induced seismic event (rock burst in the extended sense) is a complex process containing the following essential parts:

1. Brittle fracture of primary source volume

2. Emmission of energy (seismic waves, deformation steps, shocks)

3. Fractures induced by dynamic loading of highly stressed underground structures and highly loaded parts of the rock mass outside the primary source

4. Shaking the surface above and near the mine including all structures and buildings on the surface

5. Developement of a new equilibrium state in and around the underground openings and in the over- and underlying rock strata

6. Local fractures (incidental also brittle ones) as a result of the development of the new equilibrium state in the rock mass including the surroundings of underground openings.

In general all parts of a mining-induced seismic event (rock burst) will occure but depending on the real local natural and technical conditions the weights of the different parts can be very different.

Some examples should demonstrate that:

The classical rock burst in the narrow sense is e.g. an outburst of the edge of a coal seam. Part 1 is the dominating one and occurs very near to the mine working; parts 1,2 and 3take place nearly at the same site; part 4 is very small, mostly only to point out by instrumental registrations; part 5 is limited to the immediately focal zone, too.

The case of "sudden failure of a residual pillar within the goaf" shows a clear part 1 very distant from the activ mining workings; also part 2 will be, of course, and part 3 can be, depending on the value of emitted energy and on the strength conditions of the contour zones of the nearest active openings. Often, the parts 4 and 5 are perceiveable and part 6 can occure, occasionaly, in openings at the edge of the goaf.

The mining-induced seismic events in the Saskatchewan potash mines /20/ show the parts 1,2,4 and 5 but not part 3 because of the lack of sensitivity to dynamic loading of sylvinitic salt rocks in the mine.

In the opposite the very powerful mining-induced seismic events in the German potash mines /12/ show the same parts of the burst process as those of Saskatchewan but additional very clear parts 3,5, and 6. The part 3 is here dominating due to the sensitivity to dynamic loading of the high stressed carnallitic pillars.

The "large area rock bursts" in the mines of Kolar Gold Fields in India /21/ are typical examples for dominating parts 1, 2, 5 and, particularly, 6. One big "bump" (parts 1 and 2) is accompanied by a number of small single rock bursts in a relatively narrow time window at different places of the mine (parts 5 and 6).

On the base of a characterisation of the rock burst process by the 6 parts, one can use and compare the local technology- and geology-dependent classifications. It is important to point out the relations of the local events to the 6 parts of a generalized rock burst (mining-induced seismic event) and not longer to exclude some events from the phenomenon "rock burst" if one or more of the 6 parts are not so clear recognizable or not present.

Some examples should be given for the correspondence of classical terms of rock bursts and the 6 parts of the rock burst process:

- "rock shooting" /e.g. as defined in /22/: It is a micro-rock burst, consisting only of the part 1 and a very small part 2.

- "bump" (e.g. as defined in /6/): The terminus bump stands in the literature for a rock burst with dominating part 1 distant from the workings and, partially, no part 3.

- "rock fall"(e.g. as defined in /6/): Rock fall is excluded from the mining-induced seismic events by the definition; it is no rock burst because the source of emitted energy is only the gravity field;the other sources are not actively, immediately, and the primary fracture process is not a brittle one.

"tectonic rock burst"(e.g. as defined in /11/): In tectonic rock bursts, as a rule, all 6 parts of the rock burst process are clear developed and the tectonic rock bursts are therefore the most powerfull and damaging ones.

- "pillar burst" (e.g. as defined in /22/): A pillar burst is a clear local fracture with dominating part 1 and the occurrence of parts 1, 2 and 5 at the same place (pillar).

CONCLUSIONS

The very complex phenomenon "rock burst" should be understood as a "mining-induced seismic event" presenting as a complex fracture process. The process consists of six parts. The parts can occure more or less simultaneously but they can have very different weights or single parts can be absent, respectively, if the local conditions are not given for one or the other part. That means on the other side, if the conditions for the single parts are changing in time or space the features of rock bursts can change, too. So, a "bump" (part 1 is dominating far from the openings) can develope very quickly to a "tectonic rock burst" if the mining operations reach geological zones, which rocks are high stressed and sensitive for dynamic loading. Otherwise, one can change the very dangerous "tectonic rock burst" into "bumps", not dangerous for the underground openings in the mines if one can change the sensitivity for dynamic loading of the adjacent rocks of the openings into a state of unsensitivity. This conception will be used e.g. in the Tkibuli-Shaorsk-coal deposite /19/.

The formulation of the complex rock burst process is therefore a usefull tool

- to recognize the full interaction of the single parts of the process,
- to direct the measures for prevention, prediction, and combating to the real primary reasons of the burst,
- to evaluate better a possible change of rock bursts in the course of the development of the mining extractions in time and space and
- to give the very different local definition and classification systems a common base and to make possible the comparison of case studies in different mining districts.

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DEFINITION

1. Rock bursts are mining-induced seismic events.

2. Mining-induced seismic events are sudden, brittle fractures of parts of the rock mass within the influence range of the mine

3. The sources of stored and emitted energy are tectonic stress field, gravitational stress field, immediately and mediately mining-induced stress fields

4. Rock bursts can result in destructions underground and at the surface

Fig. 1: Main features of rock burst definition

ROCK BURST PROCESS

1. Brittle fracture of primary source volume

2. Emmission of energy

3. Fractures induced by dynamic loading of the rock massif

4. Shaking the surface above and near the mine

5. Development of a new equilibrium state

6. Local fractures as a result of 5.

Fig. 2: Components of the complex rock burst process