УДК 622.281

BEHAVIOR OF THE HANGING WALL - COAL SEAM ARRANGEMENT USING THE IMPACT THEORY AND RESONANCE SYSTEM IN THE ROCK BURST CONTROL IN CONDITIONS OF OSTRAVA – KARVINA COALFIELD

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The article researches is to present the specialized public a new look on the behavior of the arrangement employing the impact theory or the resonance system with the contribution of free and induced oscillations, regarding the forces inhibiting the rock burst rise in the saddle-shaped strata of the Ostrava – Karvina Coalfield as well as their phenomena interacting with induced seismic activity.

Keywords: transient effect, coal seam, building elements, “hanging wall – coal seam”, genesis

Abstract. The arrangement (hanging wall – coal seam) of the saddle-shaped strata in OKC (Ostrava – Karvina Coalfield) is burdened with oscillatory variations resulting from the motion of the earth’s crust bedrock – SIAL (tectonic stress and shocks i.e. natural seismic activity of free and induced oscillations occur) as well as due to mining operations (i.e. induced seismic activity). That means, the bedrock itself is constantly tuned in the oscillating motion. The frequency of the oscillations is then closely bound with the dimensions of the oscillating solid, seam thickness, tectonics, and the surface dimensions of the oscillating layers (elements *A*, *B*, *C* of the arrangement shown in Fig. 1), with physical-mechanical properties of the arrangement and the mining method (i.e. increase in stress showing thus the incidence of static load due to inertial forces) and the arrangement may be brought to the genesis of a rock burst either by the impact stressing (transient effect) or by the resonance (steady state) and that is enhanced by the activity of the

phenomena in the arrangement as well as by the superposition taking part in the bedrock building elements (i.e. by the sum of static stresses and dynamic harmonics caused by the oscillating arrangement). To get some conceivable mechanics for a rock burst genesis in a model form, we can put down this equation:

$$\psi_{HO_{(t)}} = \sum\nolimits_1^n \psi_{\sigma_{st(t)}} + \sum\nolimits_1^n \psi_{\partial_{(t)}}, \text{ where}$$

$\psi_{HO_{(t)}}$ – is the rock burst genesis in the oscillating arrangement of the bedrock building elements (or the elongation of the oscillating arrangement of the bedrock building elements);

$\sum_1^n \psi_{\sigma_{st(t)}}$ – is the superposition of static stresses in the oscillating arrangement of the bedrock building elements;

$\sum_1^n \psi_{\partial_{(t)}}$ – is the superposition of dynamic harmonic oscillations of the bedrock building elements (or the dynamic gradient of harmonic oscillations of the bedrock building elements).

Introduction. The mining activity itself can be considered as an anthropogenic interference into the bedrock whether or not it is done by open-pit digging or by underground mining.

In my work I deal mainly with the problems in underground coal mining, especially in the longwall mining.

As you know, mining is a plundering business. Its principal feature is that after extracting the industrial mineral (a coal seam in this instance) the stress deformation state of the bedrock is changed, because it is now affected by such a mining activity – by extracting specific building elements out of the bedrock.

In general, the bedrock can be considered to be a relatively separate arrangement. In this work, we will primarily take an interest in manifestations of this relatively separate arrangement in terms of swift impulse actions – oscillations of the bedrock building elements, but in order to get a mathematical model, it will be considered to be a coherent solid (continuum) with its mass uninterruptedly distributed.

Numerous experiments, by Board (1983), show that many results obtained from them are favorably corresponding with the conclusions related to the conception that the mass of solids under consideration is distributed coherently and that this distribution varies only due to effects of heat and force. In the case of coal mining, we do not consider the heat effect because the temperature variation in the bedrock building elements is in the range of a few tens of degrees and this cannot essentially affect the behavior of the building elements.

When neglecting the effect of temperature variations, then the elementary description the bedrock is accomplished by:

- describing the stress state
- describing the deformation state

Materials to compile this researches were mostly obtained in the course of solving the geophysical project in collaboration with the Caustobiolite Deposits Research Institute, Ltd. Ostrava along with examination of seismic activity by means of our regional diagnostic polygon. The substantial amount of information was conditioned by examining the particular situation in the geomechanics of Ostrava-Karvina coal mines. General results have been published in technical papers at home as well as abroad.

The purpose of this researches. The purpose of this researches is to present the specialized public a new look on the behavior of the arrangement (hanging wall – coal seam) employing the impact theory or the resonance system with the contribution of free and induced oscillations, regarding the forces inhibiting the rock burst rise in the saddle-shaped strata of the Ostrava – Karvina Coalfield (OKC) as well as their phenomena interacting with induced seismic activity.

Existing researches, research tasks and final reports have dealt with solving such an effect in the rock burst control regardless of the effects of oscillations, impacts and resonance within the bedrock of the OKC.

Along with comprehensive monitoring and due to author’s personal longstanding practical experience with impact theory and resonance in the bedrock, a new view of solving the mechanics (and simultaneously the feasibility of prevention) in the rock burst control in OKC starts appearing.

This newly compiled original researches deals with the behavior of the arrangement hanging wall – coal seam using the phenomena of oscillation and impacts as well as the resonance system of the arrangement applied in the rock burst control in conditions of the saddle-shaped strata in OKC.

With the present-day level of knowledge on the character and mechanics of the rock bursts, let us say, knowing the conditions for safe drive of workings, it is advisable to present the competent public for their consideration also other views of feasible solutions to this problem.

This researches should be of service to this purpose. It is evident that the solutions presented here do not apply to wide spectrum of possible rock bursts (e.g. the substratum rock bursts are not solved here), however, this researches offers one of the guidelines how to solve the genesis of a rock burst using the oscillation and impact theory and the resonance system, considering the forces inhibiting the rock burst genesis in conditions of the saddle-shaped strata, based on well known results obtained from geophysical monitoring in situ published by Knotek (1980), (1985), (1997).

Partial conclusion. It is well known that the coal seam is the weakest building element of the bedrock in most of the coal deposits situated close to the operational workings. That is why the processes reshaping the existing seam are usually crucial for the rise of rock bursts, eventually for tremor phenomena. The individual coal seams usually have complex structural compositions and their individual macropetrographical locations are characterized by diverse thicknesses, elasticity, etc. On top of that, the coal seams are usually disrupted by a number of secondary areas with mechanical discontinuities induced by previous mining so that the ability to reshape these seams is mostly determined by the arrangement and the extension of deformations in such locations of the seam that are adjacent to the workings.

Therefore, the mechanics of rock burst events cannot be understood separately, see Bukovansky (1997), as the mechanics showing independent behavior of the bedrock, but on the contrary, in its relationship to increasingly growing number of disruptions throughout the bedrock caused by partial processes occurring around the workings, each of which constitutes conditions leading to prospective activation of the subsequent processes and making them acute. When dealing with rock bursts, it is then right to assess and pass judgement not only on general conditions in the existing deposit, but also on the special conditions of mining at the same place.

Note: The rocks, in view of layers in the saddle-shaped strata in OKC, are mostly noted for the fact that they do not have the same mechanical qualities in all directions. Our arrangement is considered to be transversal one i.e. 1 x isotropic and 2 x anisotropic.

Existing situation. Several theories describing the origin of rock bursts are known from the specialized publications worldwide, that are based on locating the rock burst event, the distance of the rock burst focus from the coal face, on the magnitude of seismic energy released with the rock burst as well as on the mechanical qualities of the seam and its surrounding rocks, see Cook (1975) Jaeger (1969), Jeremic (1985), Obert (1967), Peng (1984), Salamon (1983), and Wilson (1984).

It is necessary to claim freely that none of the theories published in the specialized publications worldwide, presented even in some works listed as the references to this work, does not fully explain the wide spectrum of conditions and the character of symptoms leading to the rock bursts. It is then necessary to go on dealing with such problems broadly so that we can get more versatile view of this phenomenon and reveal its mechanics along with elaborating more effective operational methods to prevent rock burst hazard.

Present situation – source. The equation describing the prospective genesis of a rock burst (HO) has been put down as

$$HO = \sum_{1}^{n} \sigma_{st(t)} \text{ where } \sum_{1}^{n} \sigma_{st(t)}$$

are superpositions of the static stress and the predetermined or predicted factors (e.g. mechanical qualities of rocks and coal, depths of strata in direct and upper hanging walls, the effect of tectonics in the residual pillar or that of coal face borders in the hanging wall). Science and research have been interested so far in searching for new factors affecting the disruption of the bedrock (HM) not only in the primary stress field, but largely in the secondary induced stress field. Up to this day, published by Vesela et al. (1991), they have defined and registered more than 100 processes affecting the forms of disruption of the bedrock. In this way, however, they still get to the static state, which corresponds with the fact that not all the symptoms of the bedrock pressures and like, registered in advance, are only brought about by the static stressing.

Model system of the oscillating of the hanging wall – coal seam arrangement. The bedrock, as part of the earth‘s crust in the existing locality, is a quasistatic solid. Owing to some slow motions in the earth's crust caused by continuous changes and motions of the substratum (SIAL), flowing and rearrangement processes in magma environment right beneath the earth's crust are in progress. This results in continuous tectonic stresses and shocks in the crust (natural seismic activity) caused by disrupting the earth's crust so that the bedrock itself is always tuned in these oscillating motions. They may be observed especially in the event of earthquakes, but it is apparent from seismic registrations and monitoring that the bedrock oscillates all the time.

The hanging wall –coal seam – substratum arrangement, in which we are interested here most, must oscillate too.

Owing to conditions that are common in OKC (the conditions in the saddle-shaped strata) we can assume that the resonance frequency will vary from a few single oscillations up to 10 Hz, whereas the respective (free) frequency of the bedrock building elements will be rougly in the same proportion by Bukovansky (1998). This datum of mine results from the geophysical polygon of the company Dulni pruzkum a bezpecnost, a.s. Paskov OKD which has been registering such frequencies in most of the cases.

Due to mining and other activities brought about by anthropogenic effects to nature in our environs, such induced changes must necessarily occur as a result of disrupting the initial quasistatic state of the bedrock. These induced effects make themselves felt mostly through the induced seismicity of the bedrock and they can be described as seismic wave energy of various kinds and origins. The following mining activities and operations primarily belong here:

- seismic effects caused by blasting in the course of conducting the mining operations;
- seismic waves or impacts caused by disruption of thick and solid hanging walls piling up the mined-out longwalls;
- seismic waves brought out by activation of tectonic motions along the existing tectonic areas, etc.

All the seismic shocks – foci (i.e. natural and induced seismic activities) may have diverse forms (in relation to discontinuity and heterogeneity of the bedrock) ranging from the seismic waves similar to earthquake to the effect of intensive distant tremors (e.g. in the OKC of the Polish section of the Upper Silesian coal basin) as well as impacts and strokes of various kinds and origins, having generally the form of sustained and damped oscillations.

At all locations of the bedrock, these seismic tremors are superimposed into a single form causing a wave motion which may even induce the disruption of the bedrock building elements at the respective location with all the effects resulting from that (if the stress in the bedrock and the initial stress level in the respective location, due to seismic effects, are simultaneously exceeded).

If this disruption happens in a location far beyond the operational workings, it is a tremor and if this disruption occurs close to the operational workings, it is either an impact or even a rock burst.

As you know, the seismic waves, while running across a boundary (e.g. via discontinuity, heterogenity), may change their amplitudes and characters (e.g. transient effect, steady state); they may reflect, refract, etc. That is why prediction of the induced seismic activity impacts on the anthropogenic activity is considerably uncertain, both in time and space. On this account, there are enormous problems with implementation of the rock burst control by geophysical prediction e.g. by using the outcomes from the geophysical polygon in OKC.

The oscillations in a relatively separate arrangement can be looked upon as the recurrent transfer of a specific amount of energy from a solid to a spring and vice versa, twice in each cycle. When a spring is stretched out or pressed down to the limit ($\psi = \pm A$) (where A is an displacement amplitude of the oscillating arrangement of the bedrock building elements, ψ – instantaneous displacement of the oscillating arrangement), oscillating arrangement mass – m, the solid is immediately brought to a stop and the kinetic energy dies out. At this moment, the total energy of the system is being stored in the spring in the form of the potential energy. As the solid comes through the point ($\psi = 0$), it is given the top speed equaling to $\dot{\psi} = \omega_0 A$ (where ω_0 is the free (natural) oscillation of the bedrock building elements) and its motion concentrates all the energy of the system in itself because the spring is neither stretched out nor pressed down. In other spots of this system the proportion of kinetic energy to potential energy is changed, but their sum is always the same in a single arrangement. That is why we are now going to analyze the oscillating process of the bedrock arrangement in general.

The free motion of the arrangement has an oscillatory character. The mass is given the acceleration:

$$\ddot{\psi} = d^2 \frac{\psi}{dt^2}, \qquad (1)$$

which is determined by the second Newton’s law

$$m\ddot{\psi} = Q_N, \qquad (2)$$

where Q_N is the force of the oscillating arrangement (hanging wall force). It is achieved during the period before the equilibrium, certain velocity and corresponding momentum are reached so that it may overshoot to the other direction. Both the flexibility or rigidity of the arrangement as well as the mass inertia are the essential conditions for the oscillatory motion in the bedrock. The rigidity ensures that the mass tries to revert to its equilibrium state, but the inertia will make the arrangement to be overshooting.

The motion equation (2) is a differential one of the second order, on the basis of which we wish to find a scientific notation determining the dependence of ψ on time t. This equation is too indefinite. In order to get quantitative results, the simplest possible assumption is that the force of the the oscillating arrangement Q_N is proportional to the instantaneous displacement of the oscillating arrangement ψ.

So we can put down:

$$Q_N = -k\Psi, \qquad (3)$$

where k is a positive constant well known as the spring constant or the rigidity of the oscillating arrangement.

With this assumption our arrangement possesses now all the qualities of a fictitious entity which is well known in physics as the harmonic oscillator.

The motion equation (2) now verges into

$$m\ddot{\psi} = -k\psi. \qquad (4)$$

In order to transfer the results, we are going to deduce, to our oscillating arrangement more easily, we will transcribe this equation into standard form and we will talk about the dynamic harmonic oscillator of the bedrock building element:

$$\ddot{\psi} + \omega_0^2 \psi = 0, \tag{5}$$

where the new positive quantity ω0 is expressed by the equation

$$\omega_0 = \sqrt{\frac{k}{m}}. \tag{6}$$

The common integral of the equation is:

$$\psi(t) = A\cos(\omega_0 t + \varphi), \tag{7}$$

where A is the displacement amplitude of the oscillating arrangement of the bedrock building elements, φ is the phase shift and $\psi(t)$ is the instantaneous displacement of the harmonic oscillatory motion of the bedrock building element.

If a quantity depends on time in this manner, we say that it alternates in a harmonic way. The oscillation, due to which ψ alternates harmonically, is known as the harmonic motion. This harmonic motion is periodic and it repeats itself endlessly in a number of identical cycles after elapsing some of the time t.

The effect of elastic arrangement hanging wall – coal seam solid upon oscillations of the bedrock building elements. The elastic arrangement of the hanging wall – coal seam can be illustrated as per Fig. 1.

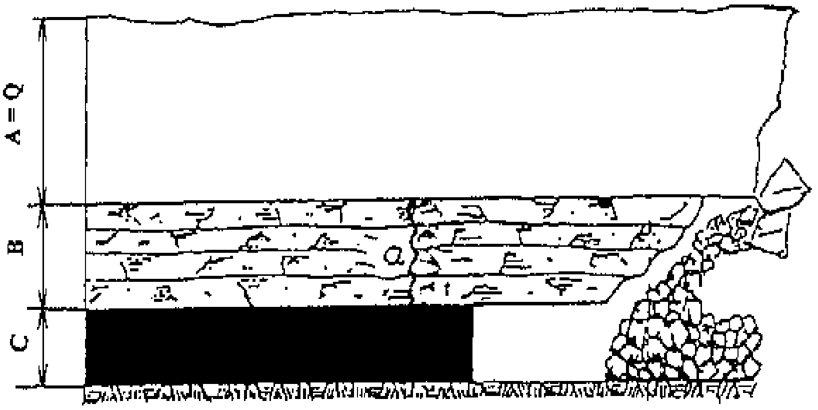

Fig. 1. Illustration of the elastic arrangement: hanging wall – coal seam

This elastic oscillating arrangement includes oscillating element *C* (coal seam), intermediate primary hanging wall *B* and burden *A* with weight *Q*. The weight of elements *B* and *C* in this arrangement is low in comparison with that of element *A* and thus the behavior of this arrangement is mostly determined by element *A* (its thickness is up to 200 m).

The qualities of the oscillating arrangement are then determined partly by the properties of its single elements, partly by their weights and rigidity and by the oscillating motion velocity.

As mentioned above by Bukovansky (1998), the oscillator is a set of solid particles capable of performing oscillatory motions.

The bedrock or the coal seam, as the oscillating system, may have any number of degrees of freedom and hence we replace continuously distributed mass of this elastic solid with multiple small solid particles capable of oscillating both in plane and space, see Bukovansky (1997).

If a mass particle oscillates, which is now the case of the infinitesimal building element of the bedrock, in continuum, a motion starting up in the respective surroundings, is called the wave motion. This wave motion is only peculiar to the nearest surroundings of the respective mass particle, whereas the energy of the oscillating particle can go over to the neighboring particles and make them oscillate by Bukovansky (1998).

The arrangement, illustrated in Fig. 1, may be stressed not only due to the oscillations specific for its surroundings, but also owing to the oscillations and waves coming from the remote surroundings due to mining conditions e.g. caused by transforming the bedrock in the respective coal mine or in its neighboring collieries (the collapse of the roof above the coal face, etc.), or generally, even due to the waves coming from distant earthquake epicenters. In this case the superpositions of waves occur by Bukovansky (1998).

In another case, this arrangement may be stressed by an impact i.e. by an oscillation induced e.g. by disrupting the primary hanging wall, element *A*, see Fig 1.

Also here, generally speaking, element *A* represents the primary hanging wall, element *B* is the immediate hanging wall and element *C* is the coal seam. The omnibus model of the oscillating arrangement followed by us, evident from previous (Fig. 1).

All the possible forms of oscillatory stressing, the arrangement of bedrock building elements is exposed to.

There may be oscillations of the entire arrangement, as a continuum; i.e. all of its elements *A*, *B* and *C* may oscillate altogether without being disrupted as well as there may be the superposition of oscillations peculiar to the arrangement due to the wave motion coming from a farther area (Z foci), or such oscillations may be caused e.g. by an incoming impact from the disrupted element *B* perhaps also from the disrupted element *A*.

The influence of inertia forces and the harmonic oscillation dynamics of the bedrock elements. The regularity of motion is characterized by the fact that the velocity $\dot{\psi}$ of investigated elements of the moving arrangement is not changed i.e. the single particles of the bedrock building elements arrangement are neither accelerated nor decelerated. If the bedrock building element arrangement has acceleration $\ddot{\psi}$, then the effect of dynamic stressing of the oscillating arrangement is characterized in this way.

There are practically diverse kinds of acceleration at the boundary of two touching bodies for instance, the upper hanging wall – primary hanging wall – coal seam, Fig. 1.

A swift change in velocity of the bedrock building elements or that of a coal seam, caused by stressing the neighboring elements, results in an impact whereas even such rocks that are resilient or quasiplastic under static stressing (e.g. coal seam) may appear to be breakable. The impact of acceleration of single particles of the coal seam on the state of stress in its building elements can be conceived in the following manner. If the coal seam is moving with acceleration, it must be affected by the forces (stresses) from other solids.

According to the law of action and reaction, both the hanging wall and the coal seam interact via their reaction forces equaling to acting forces, but they have opposite signs; they are called the inertia forces. This consideration can be obviously applied to each particle (building element) of the coal seam going on with the acceleration. These particles will act on their neighboring particles in the coal seam by internal forces, equaling to their inertia forces.

Quite real additional stresses, equal to the static stress induced by the inertia forces, come into existence in the coal seam as a result of the accelerated motion of the hanging wall. Each individual particle of the stressed solid (hanging wall – elements A, B, and C, Fig. 1) will be transferring as much stress onto its neighboring particles of the coal seam as if it were combined with an inertia force.

In terms of mining experience it may denote this:

If the acceleration is variable (i.e. due to additional loading, destressing i.e. by the coal face advancement), the arrangement (hanging wall – coal seam), as a rule, will be oscillating so much that a bouncing – impact (or resonance) may happen, boosting by this the stress energy, and consequently, the deformation energy, which leads to exceeding the strength limit and the bedrock building element gets disrupted.

Energy model of the oscillating arrangement: hanging wall – coal seam. The total energy of oscillations of the oscillating arrangement in a relatively separate system according to

$$\psi_W = \psi_T + \psi_U = 1/2\, m \dot{\psi}^2 + 1/2\, k \psi^2 \quad [\mathrm{J}], \tag{8}$$

ψ_T – the kinetic energy of the oscillating arrangement;

ψ_U – potencial energy of the oscillating arrangement;

is constant and it is determined by the equation

$$\psi_W = \frac{1}{2} m(\omega_0 A)^2 = \frac{1}{2} kA^2 \quad [\mathrm{J}], \tag{9}$$

since pursuant to (6) $k = m\omega_0^2$. The total energy of the oscillating arrangement for the respective solid and spring is proportional to the square of amplitude, but it does not depend on phase constant φ. The velocity and acceleration of the solid also oscillates in a harmonic manner with the same frequency as the instantaneous displacement ψ of the oscillating arrangement does. Since the displacement and velocity are shifted in phase by π/2, the energy flows to and from between the solid and the spring twice in each cycle, see Main (1990).

The course of both energies, by Bukovansky (1997), is periodically changed with time.

In terms of mining experience this can be visualized e.g. by the phenomenon of periodic collapses taking place in the coal face. With the coal face advancement the collapse of the upper hanging wall is constantly lagged behind and the hanging wall just bends slowly down, but it is relatively inactive. The position of the upper hanging wall beam is not changed then, but the potencial energy within it is constantly increasing (the hanging wall arrangement is bending, there is delamination, the beam length is extending). If this beam gets disrupted, a glimmer will turn up, and all the potencial energy is virtually turned into kinetic energy to revert again to potencial energy at the moment the disrupted beam of the hanging wall impacts on the foot-wall of the mined-out seam, or on the layer of caved ground in the primary hanging wall.

It is common knowledge, see Bukovansky (1997), that the rock bursts belong to the most dangerous signs of bedrock stresses induced by mining activity in underground collieries. The displacement of bedrock, which takes place due to energy release upon disturbing its voluminous state of stress, is turned with the rock burst, into the kinetic energy of the bedrock loose particles. These particles can only get into an open cavity i.e. into the working where the only reaction against them is exerted by the supports of the working.

The energy of the oscillating arrangement, coming into question in the course of the transient state – impacts, steady state – resonance on the rock burst, is then determined by the superposition:

$$\psi_{W_C} = \psi_{W_{S1}} + \psi_{W_{prh}} + \psi_{W_k} + \psi_{W_f} \quad [\mathrm{J}], \qquad (10)$$

where $\psi_{W_{S1}}$ – is the energy released from the coal seam of the oscillating arrangement; $\psi_{W_{prh}}$ – is the energy released from the adjoining rocks of the oscillating arrangement;

ψ_{W_k} – is the energy caused by the oscillating arrangement;

ψ_{W_f} – is the energy of phenomena events in the oscillating arrangement.

Each of the individual energies may contribute to the rise of a rock burst.

The ejection of coal out of the seam may be brought about by the following:

- resonance;
- impact;
- abrupt change in loading conditions, by Blaha (1983).

The principle of coal ejection out of the seam in the course of impacts and resonance is qualified by the existence of a physical boundary (seam – goaf) and following equation is then effective:

$$\frac{\psi_{\Delta U}}{\psi_{\Delta S}} \geq \psi_{W_0}, \ [\mathrm{J}], \tag{11}$$

where: $\psi_{\Delta U}$ – is the change in elastic energy density around the boundary of the oscillating arrangement [J.m^{-2}];

$\psi_{\Delta S}$ – is the unit area of the oscillating arrangement boundary [m^2];

ψ_{W_0} – is the essential energy to disrupt the mass of the oscillating arrangement.

In case the left part is equal to the right one, the ejection of coal will not happen, but the process of seam disruption will only take place. Amended by Konecny et al. (1990).

Summary. The fund of accumulated elastic energy of the oscillating arrangement in the critical spot of the bedrock must be able to cover the energy spent on resonance (impacts), disruption, dissipation and on delivering the kinetic energy. The process of accumulated elastic deformation energy always goes along with the changes in stress and deformation of the bedrock building elements, or by inducing anomalous stress fields in which predispositions of focal regions exist – i.e. oscillations of the bedrock building elements. The source of elastic deformation energy in the coal seam is found in its variable stressing at the area ahead of the driven working, see Blaha (1983). Considering the balance of forces, significant roles are also played by the friction forces at the joint of the coal seam with its surrounding rocks, see Bukovansky (1997). The common feature to clarify the rock burst mechanics, as a result of oscillations, is the principle of switching the mechanical arrangement from one stability level to another by a step change. At the moment of such switch the arrangement is found in an unstable state, which is the keynote of Salamon's model. The details can be found in Salamon (1983).

In terms of mining experience, it may denote that owing to oscillations, impacts and resonance, the arrangement turns, on certain conditions (transient effect, steady state, physical and mechanical properties of the bedrock, by mining, acceleration, etc.) into unsteady state and due to the concentration of stress energy and phenomena effects, it is ready for the possible rise of a disruption (by dynamic deformation), which expresses the irreversible process of stress decline with the deformation enlargement. The rocks, Young's modulus of which is lesser than that of clastic deformations (beyond the strength limit), are subject to dynamic disruption (they are fragile) and hence there is the possible rise of a rock burst.

Behavior of the external force variable in time – the resonance. If the oscillator of the bedrock building elements oscillates in the environs showing damping (resistance – friction), the energy will be decreasing with each cycle by the value, which is necessary to overcome the friction of the arrangement resistance and that is why the oscillations will fade away in a few moments. To keep the oscillations going on, it is necessary to add the energy, which the oscillator is losing with each cycle, by an excitation force. This can be accomplished by the work of external force variable in time.

$Q(t) = Qo.cos\ \Omega.t$, where Qo is the amplitude of the external force variable in time Ω is the radian frequency of the excitation force t – time.

Before the resonance sets in, the oscillating arrangement must run into steady state just because of the action of excitation force. If the excitation force was acting for much longer time than 1/b ($b = B/m$; B – a positive constant, the resistance – friction of the oscillating arrangement under damping since the free oscillations ω_0 will get gradually diminished ($b_t \ll 1$) pursuant to the resonant curve with various damping levels, b – attenuation band), we can then expect that the oscillating arrangement runs into such a mode in which the mass and excitation force will be oscillating harmonically with the same frequency. The displacement will not necessarily be in phase with the excitation force, but the phase difference should reach a constant value.

Free oscillations of the undamped arrangement are dominant and they are an example of the steady state that is determined by the displacement of enforced oscillations.

$$\psi = A cos(\Omega t + \varphi), \tag{12}$$

where radian frequency Ω equals to that of excitation force (not to the frequency of free oscillations). Amplitude A and phase constant φ (displacement angle) are not arbitrary and they are determined for our arrangement by means of Q_0 and Ω.

In terms of mining experience, it may denote that in the stage of steady oscillations, owing to the advancement of coal faces (with the development of individual phases: transient effect – steady state), vertical, lateral as well as temporal migration of zones with critical stress energy concentration is taking place (i.e. when elastic deformation energy is of a high order) in the surroundings of the mined out coal seam area and this gives rise to an impact or a resonance, consequently, to a rock burst.

The excitation force of the bedrock building elements may come into existence for various reasons for instance, by the incidence of a wave on the coal seam able to oscillate, or by redistributing the stress within the coal seam and adjoining rocks, due to disruption of the bedrock building elements caused by e.g. shot firing consequent on shear and tensile stresses. It is common knowledge that the disruption of rocks generates at least the seismoacoustic waves with diverse quanta of energy, being proportionate to the extent of this disruption. Based on numerous measurements in situ, it is well known that heavy laden rocks pass through the deformation on a small area and that this deformation may give rise to the release of energy from the bedrock building elements, and eventually, bring along the formation of free or forced oscillations.

It is then clear that the excitation force, however it comes into existence, is characterized in these ways:

- it performs work;
- it acts in the direction of motion;
- it has periodic time response and;
- it supplies energy permanently.

It is evident from the practical example of the resonance (impact) genesis in OKC that various cases of resonance might happen in mining when the external force variable in time, causing the excitation of the oscillator, has a different character than the influence of the upper hanging wall on the primary hanging wall around one of the coal faces. The actions of the hanging wall upper layers on the primary hanging walls of remote coal faces are very frequent where, due to resonance, only the disruption of primary hanging wall of the affected coal face may occur, without being directly influenced by the oscilla-

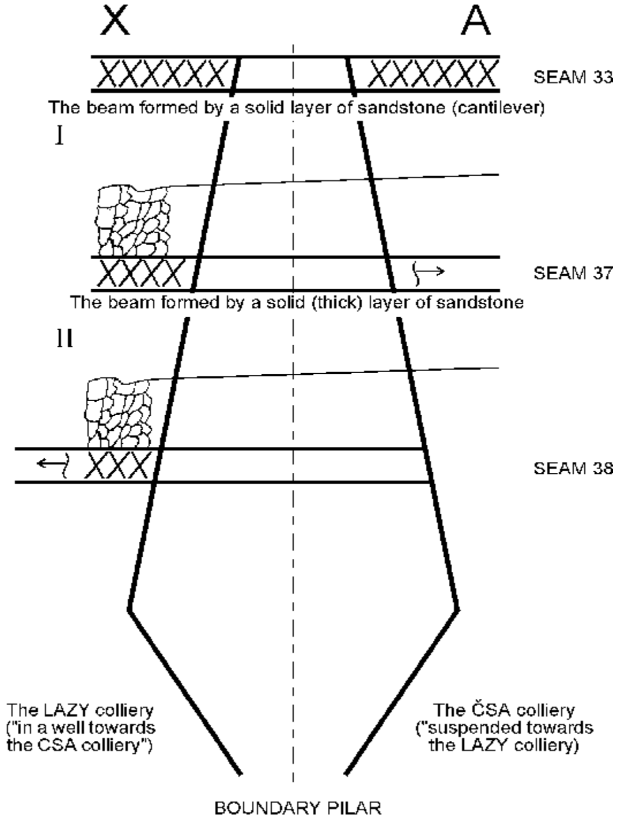

Fig. 2. Real mining situation at the boundaries among collieries caused by resonance (impact)

tor arrangement of the solely affected coal face. They are quite frequent cases in mining profession when, due to a tremor or strata disruption in another coal block of the colliery, some symptoms of the bedrock disruption might occur, because of the resonance, even in the form of a rock burst in a relatively remote location (e.g. beyond the colliery boundaries), especially if levels of digging in neighboring collieries are different (CSA Colliery – the Lazy plant site), see Fig. 2.

Suspended layers I and II (cantilevers) of the thick hanging wall solid strata, belonging to the worked-out seams I and II, may slowly oscillate due to mining operations and the collapse above the coal faces of neighboring colliery A, see Fig. 2, and/or the resonance effect may take place (or the superposition of oscillations and impact), plus the disruption of cantilever I (or even cantilever II) and the rock burst rise in the areas affected by impacts owing to these disrupted cantilevers – caused by weight Q, acting on the solids from the collapse of the primary hanging wall – cantilever B in the corridor, "in a well” X, may occur. In the same manner, due to the resonance, a retarded collapse of cantilever I or that of cantilever II may come out even due to the collapse (tumbling) of cantilever – weight Q in area A (so-called the upper hanging wall tremors).

Summary. The resonance conditions in the arrangement coal seam – bedrock in the saddle-shaped strata of OKC are generally determined:

- by action of the harmonic excitation force ($-k\Psi + m.g$);
- by sufficiently thick hanging wall of the stressing element A with burden Q, Fig. 1;

- by doping the phenomena events or;
- by superposition of the arrangement.

Conclusion. The contribution of this researches to existing problems is in presenting one of the tips on how the arrangement (hanging wall – coal seam) behaves by using the impact theory and resonance system with contribution of harmonic oscillations in rock burst control, considering the forces inhibiting the rock burst rise in conditions of coal seams in the Ostrava – Karvina Coalfield. The above mentioned cases, presented in this researches, represent typical and possible cases of the rock burst genesis as a result of oscillations, impact, resonance, superposition and their phenomena events.

Let us bear in mind that the following conditions should be taken into consideration upon evaluating the feasible mechanics of the rock burst genesis:

- oscillations of the bedrock building element (natural seismic activity);
- induced seismic activity;
- geomechanics phenomena;
- superposition;
- examination of mining methods and the quality of prevention.

All of them get involved “in the scene” for the potential genesis of the rock burst mechanics, but they do not need to i.e. each of them may get involved separately.

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ПОВЕДЕНИЕ ПОВЕРХНОСТИ ЗАВИСАЮЩЕЙ КОНСОЛИ С ИСПОЛЬЗОВАНИЕМ ТЕОРИИ И РЕЗОНАНСНОЙ СИСТЕМЫ ВЛИЯНИЯ В УПРАВЛЕНИИ МАССИВОМ ГОРНЫХ ПОРОД В УСЛОВИЯХ МЕСТОРОЖДЕНИЯ ОСТРАВА-КАРВИНА

Целью данной статьи является представление специализированной общественности нового взгляда на поведение устройства, использующего теорию удара или резонансную систему с вкладом свободных и индуцированных колебаний, в отношении сил, сдерживающих подъем взрыва породы в седлообразных пластах угольное месторождение Острава - Карвина, а также их явления, взаимодействующие с индуцированной сейсмической активностью.

Ключевые слова: переходный эффект, угольный пласт, строительные элементы, «зависающая консоль - угольный пласт», генезис