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THE RESULTS OF “VIBRATION-SEISMIC-MODULE-SOLID MASSIF-DISTURBANCE” SYSTEM SIMULATION MODELING

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Paper is devoted to study of interaction of a mechanic harmonic generator – the vibration-seismic module - and a coalbed. As a result there are qualitative and quantitative dependences of distribution of elastic seismic oscillations in a coalbed.

Keywords: mechanic harmonic generator, massif, elastic seismic oscillations, massif particles' dislocation.

In the result of complex, analytical and experimental research dedicated to the development of adaptive method of impact onto the coal solid massif, as well as due to the outcomes of determination of internal parameters and output indicators of vibration hydraulic executive elements and parameters of their interface with the massif there had been analytical dependences and its graphical interpretations defined that shall be verified for compliance to field values [1].

Since the experimental research under mining environment sets forward particular difficulties - quite sufficient and frequently justified due to production conditions - there had been computer-based experiment fulfilled. This type of approach for development of new techniques and technologies across various industries is not deemed brand new.

The nature of the research is as follows.

To enable experimental verification of the theoretical results there had been ANSYS licensed computer application package used [2]. Simulation modeling of major elements interface's dynamic processes examined both, theoretically and experimentally is targeted to provide vivid possibility to determine optimal and efficient parameters of “module-solid massif-disturbance” dynamic system, avoiding expensive experiments and using calculative approach.

ANSYS licensed computer application includes variety of extensive capabilities, such as pre-processor, solid modeling, strength, heat, magnet, hydraulic and combined types of calculations, processor elaboration of the results and their graphical interpretation. The model data (including geometry description, final elements' decomposition, materials etc) are recorded in the database by means of ANSYS processor.

The solver works directly with the information that is stored in the database and then records the results in the same database. All of the data required for the calculation are set in the course of pre-processor treatment stage. There is a possibility to select the end element type, to input material properties, create solid models and decompose them onto elements, as well as to set the required boundary conditions.

Upon completion of model development the type and parameters of the required analysis, load and its options shall be set. The indicated type of analysis shows which equations will be used to deliver the solution. In the course of pre-processor treatment stage there shall be results processing actions performed, provided the results used are those obtained during solution delivery; they may include dislocations, temperatures, voltage, deformation, speed etc.

The results may be presented graphically or in tables. ANSYS software owns powerful geometrical modeling subsystem that creates the geometry of the detail or the structure irrespective of its end element grid.

The major goal during the discrete model development stage was the creation of an adequate end element grid that contains the blocks and the elements.

When building up the end element grid the following had been taken into consideration:

– The zones that require the voltage or deformation to be defined there had been more fine grid used compared to that related to the zoned of dislocation definition;

– for nonlinearity the grid had been built so that nonlinear effects may be disclosed, the plasticity requires reasonable increase of integration points, therefore more fine grid in the zones with high gradient of plastic deformations.

There had been algorithm developed for the procedures to calculate module to solid massif to disturbance interface parameters in accordance with the assumed research design:

Definition of distribution form that is generated by the seismic wave module in the solid massif. Setting up the parameters for wave to disturbance interface.

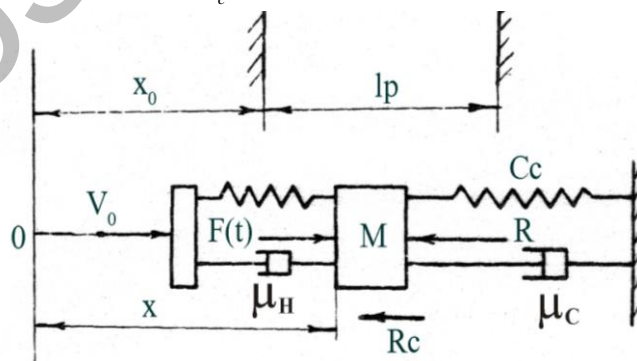
Results processing to obtain the distribution dependences for the waves reflected due to disturbance. Acquisition of specific diagrams for single and alternate impulses.

Research of beats phenomenon under the environment of forced oscillations in the massif and inherent oscillations in the disturbance. Processing of the results of reflected waves records and the delivery of recommendations to be applied to the recording equipment.

Simulation model for the interface of the vibration seismic module's executive element with the coal solid massif represents the equations system that provides the characteristics of internal parameters and output indicators of the executive element and the element that manages the vibration seismic module, parameters of module interfaces with the massif and tectonic disturbances.

The indicated similarities allow developing the equations for the mathematic model of the module based on the physical model (see Figure 1). M mass representing the combination of the reduced mass of coal solid massif that participates in the movement, main executive element and the moving liquid, is situated under the impact of forces produced by the drive $F(t)$ and R massif reaction. The drive is represented by the flexible and viscous body with the hardness coefficient C_H and μ_H , free end of the above is moving under the velocity of V_o defined by the liquid supplied by the source. The massif is also represented by the flexible and viscous body with corresponding hardness coefficient C_c and viscosity μ_c . During the movement the main executive element is situated under the impact of dissipative forces of resistance R_c . The movement of the mass is executed in the interval l_p that is remote from the conditions of initial reference point at the distance X_o . The background data for the research are reduced mass M , coefficients that characterize the properties of the impact object C_c and μ_c , the initial deformation force R_o , extent of deformation $\varepsilon = R/R_o$, maximum deformation velocity v , maximum value of deformation l_p and the reference coordinate X_o , that are linked with the ratios:

$$l_p = \frac{R_o}{C_c}(\varepsilon - 1); \quad X_o = l_p / (\varepsilon - 1).$$



M – reduced mass; V_o – reduced liquid velocity; $F(t)$ – force from the drive;
 C_H and μ_H – transmission hardness and viscosity coefficients; R – impact object reaction; C_c and μ_c –
 impact object hardness and viscosity coefficients; R_c – reduced resistance force; X_o – initial coordinate;
 l_p – movement interval; X – current coordinate

Fig. 1. Physical model of hydraulic vibration seismic module

The single cycle of the system under research includes 2 similar in nature phases of deformation and unloading. During the deformation phase the massif deforms due to the position of static balance towards the stimulating force; in the course of unloading the massif deforms – from the position of static balance in opposite direction. This cycle presumes particular boundary conditions for each period and its phases: initial dislocations, initial and final velocities are zero. Thereupon the movement within each phase is described by means of equations of one type, while the solutions for corresponding equations is defined by the set of additional conditions that are input and formulated upon occurrences. The accepted model determines the values of forces impacting the massif:

$$F(t) = P_o + C_H [V_o t - (X - X_o)] - \mu_H \dot{X}; \quad (1)$$

$$R = R_o + M\ddot{X} + \mu_c \dot{X} + C_c X, \quad (2)$$

where P_o – initial force from the drive; X and t – current coordinate and time correspondingly.

With regards to the above the differential equations of system movement will be displayed as follows:

a) during deformation phase

$$M\ddot{X} + (\mu_c + \mu_H)\dot{X} + (C_H + C_c)X = P_o - R_o - R_c + C_H X_o + C_H V_o t; \quad (3)$$

б) during unloading phase

$$M\ddot{X} + \mu_H \dot{X} + C_c X = R_o (\varepsilon - 1) - R_c. \quad (4)$$

The obtained are quadric differential equations with the right part, the solutions of these is defined by the ratio of input coefficients characterizing flexible and viscous properties of the drive and coal solid massif. The equations of module managing element are set based on the recommendations: [2]:

$$F \frac{dy}{dt} = \mu k_f \Delta \sqrt{\frac{g}{\gamma} (p_o - p_{dis} - 2p_c - \Delta p \operatorname{sgn} \Delta)}; \quad (5)$$

$$M \frac{d^2 y}{dt^2} + \Phi \left(\frac{dy}{dt}, y \right) + R_o \operatorname{sgn} \frac{dy}{dt} = F \Delta p, \quad (6)$$

where F – effective area of the cylinder; μ – coefficient of the flow through the working door of the spool; k_f – proportion coefficient used during the determination of spool's working door opening section; Δ – opening of the spool's working door; g – acceleration of gravity; γ – specific weight of operating liquid; p_o – pressure of supplied operating liquid flow; p_{dis} – discharge pressure; x – spool dislocation; y – cylinder dislocation.

Working processes in coal solid massif are described by the equations recommended by Professor Chichinin [3]:

$$U_z = U_z^o \left(\frac{R}{r_o} - \frac{z}{z_o} \right) [1 + (1 - \gamma^2)]; \quad (7)$$

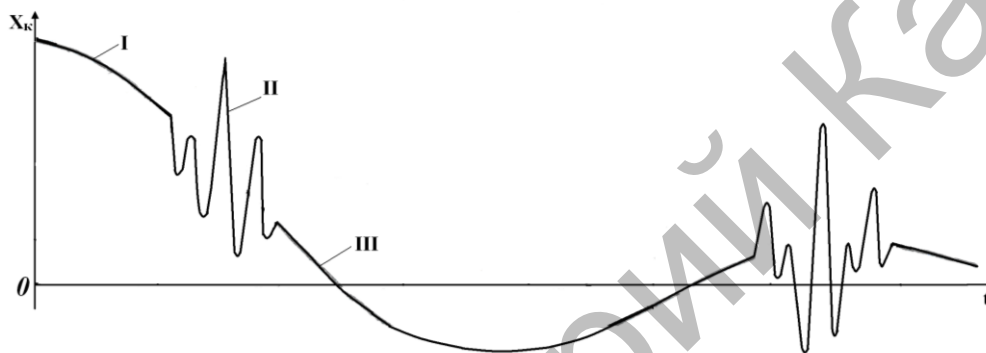
$$W = \frac{1}{2} F_{in}^2 [R_H^2 + (fM + x_H)^2]^{-1} \cdot R_H; \quad (8)$$

$$R_H = 7(1 - \gamma^2) \rho \mathcal{G}_s r_o^2, \quad (9)$$

where $U_z(z)$ – massif particles dislocation; r, θ, φ – spherical system of coordinates; r_0 – contact radius; $\gamma = \frac{g_p}{g_s}$; U_z^0 – initial dislocation (from statics); F_{in} – force amplitude; ρ – massif density; f – frequency.

The acquired system composed of 9 equations is set as a base for computer-based experiment. The analysis of the results of computer-based experiment was executed in accordance with the principle “from simple to complicated”. In accordance with this the first results were those obtained for single impulse transferred to the massif from the seismic module.

The results of computer-based experiment indicate that during the excitation of vibration seismic signal in the strata and during further wave distribution there are 3 sections of its spread: (Figure 1). These sections are differentiated by: first of all, nature of amplitude changes; reference tags will be as follows: I – the zone prior strata disturbance, II – zone of disturbance itself, III – zone after disturbance.



X_k – massif particles' dislocation; t – time I – the zone prior strata disturbance, II – zone of disturbance itself, III – zone after disturbance

Fig. 2. Quality picture of seismic wave spread across the solid massif

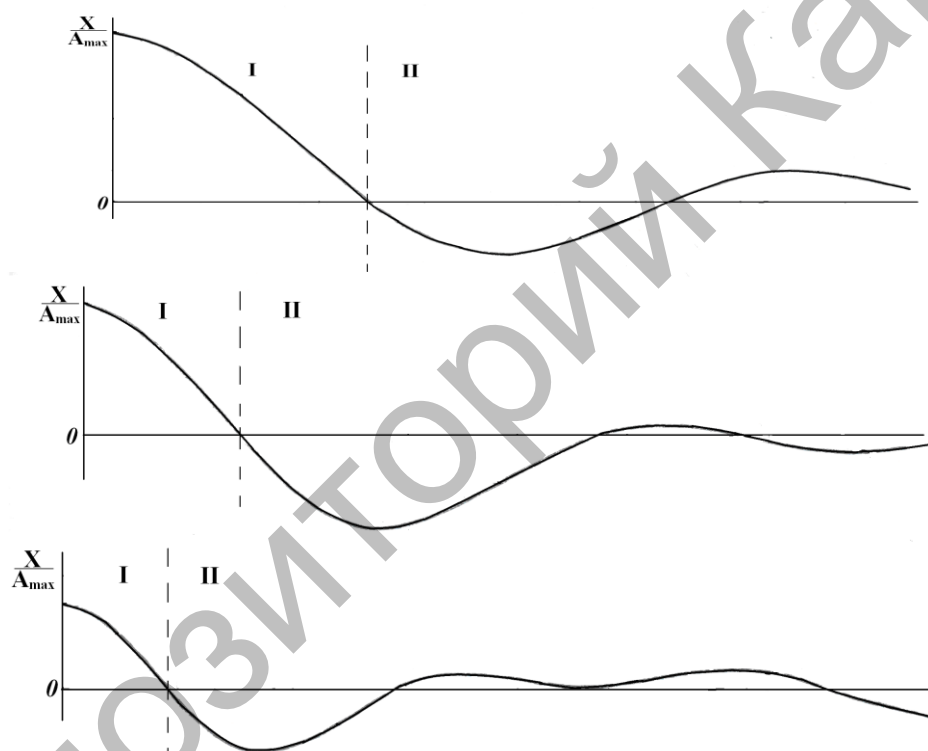
The first zone is characterized by insufficient reduce of the amplitude while remaining the frequency of the signal. This is explained by the fact that when the wave is passing through the massif it loses the energy to overcome the resistance, while keeping the frequency allows to reduce the amplitude.

The second zone is attributive of chaotic changes both, amplitude and form of the impulse. This phenomenon is explained by the fact that the volume of the disturbance is filled with the substance with physical and mechanical indicators that differ from those specific for the coal. The seismic waves passing the overall volume of the disturbance are multiply reflected from its walls, and this leads to overlap of the oscillations and impulse deformation. The nature of the deformation is defined by the sizes of the disturbance chamber and type of medium.

All of the analytical research presented during the work and its results are those for ideally flexible medium that forms the massif where the waves are distributed without the dissipation of its amplitude, while the generated signal does not change its form. This is different in reality. Any of real medium owns the dissipation property which sufficiently impacts the amplitude of the seismic waves located at the significant distance from the source. First of all the mathematic model developed for computer-based experiment shall consider the frictional forces between the particles and strata of the massif and dissipation of the energy supplied to the massif from vibration seismic module. In the result of mathematic model solutions there had been major dependences defined, such as those characterizing the amplitude of ground particles dislocation with respect to the value

of initial deformation of the breast in the point of interface with the module's executive element (Figure 3). As displayed when there is no disturbance the quality diagrams are significantly dependant of the breast static deformation value. To get abstracted from the numbers X_0/A_{max} indicator is introduced that is there to indicate the relation of the initial deformation X_0 to the maximum amplitude of the seismic signal A_{max} , transferred to the massif. It is obvious that $X_0 \leq A_{max}$, for $X_0/A_{max} \leq 1$. The dependences indicate that there are 2 dislocation zones: I – $X_0/A_{max} > 0$ – particles dislocations are observed in the direction towards signal activation zone (compression zone); II – $X_0/A_{max} < 0$ – particles dislocations in the direction opposite to signal activation zone (recovery zone). This is fairly natural because the massif is assumed to be flexible and it tends to recover its static condition.

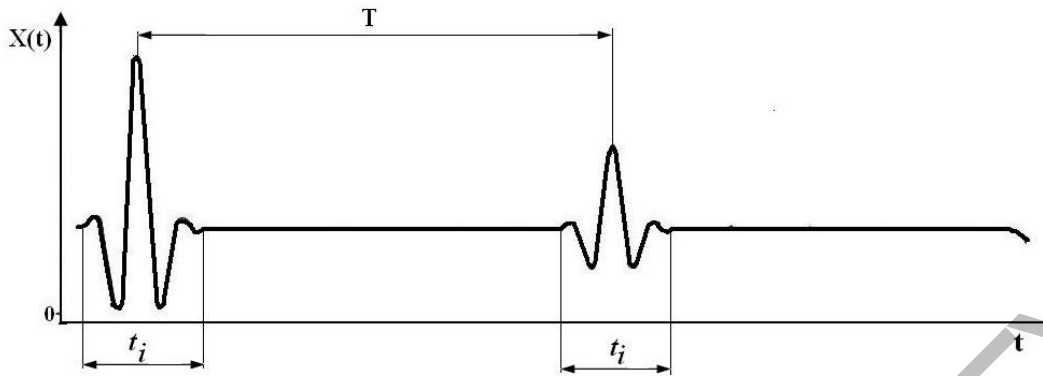
The analysis of dependences also indicates that in case of X_0/A_{max} reduction the type of the diagram changes from practical asymptote to non-periodic oscillations. The compression zone is maximal at the large values of X_0/A_{max} coefficients. From the physical point of view this is conditioned by the fact that during the minor initial deformation the massif may recover its static condition quicker.



I - compression zone; II – recovery zone

Fig. 3. Reduced amplitudes of massif particles' dislocation

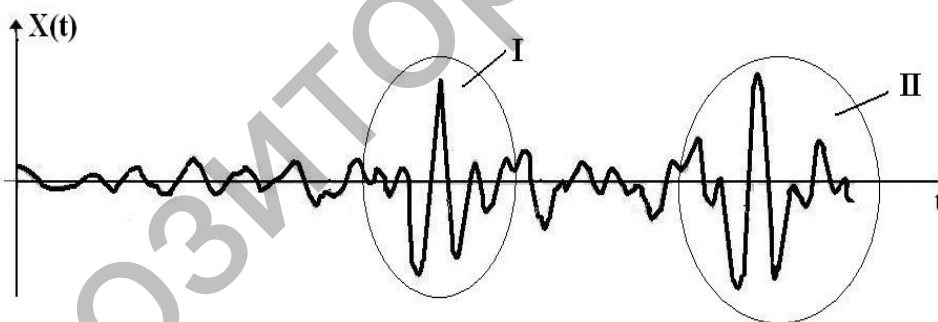
The diagram of signal change without the disturbance is described by Figure 4. It is shown on the figure that the sinusoidal impulse supplied to the breast reduces its amplitude during T time. The duration of impulse t_i remains unchanged. This is defined by the fact that the model captures dissipative forces that reduce wave energy and, hence, its velocity. The notable fact is the permanence of impulse duration under various physical and mechanical properties of the massif.



T – alteration time; t_i – impulse time

Fig. 4. Diagram of signal changes without disturbance.

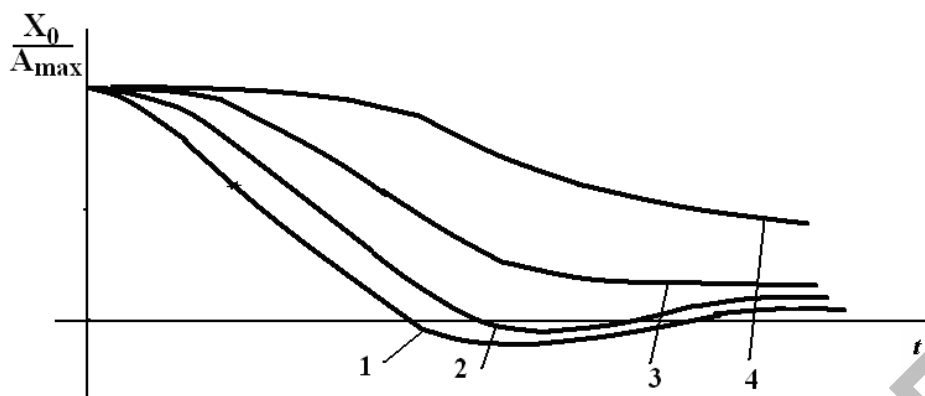
When having various types of disturbances available the diagram takes the form as shown on Figure 4. As it is seen the main curve $X_k(t)$ disrupts in the sections of disturbances and these sections are filled by the corresponding curves characterized by the properties of substances located under disturbance, and geometrical sizes. The wave dislocation being reflected from the boundaries “strata-disturbance” adopts corresponding form. The distance to the disturbance and between them is defined by means of known wave spread velocity values v_c and fixed time. The form of the signal given the disturbance is in place changes in accordance with the diagram presented in Figure 5. The sufficient result of this research is the rapid increase of the signal amplitude within the disturbance. Being reflected from the “massif-disturbance” boundaries and due to the flexible recovery forces of the massif and additional energy of the substance particles, the disturbances acquire additional velocity and thereupon the disturbance volume energy increases.



I – first disturbance; II – consequent disturbance

Fig. 5. Diagram of signal change provided the disturbance is available.

The results obtained during the modeling of alternate impulses' processes indicate the following. Quality picture acquired for single impulse under the conditions of permanent initial process environment is similar to the series of impulses. The difference is observed in terms of quantitative value and distribution of strata particles' dislocation. Figure 6 displays the results of results processing for the experiment dedicated to the massif dislocation amplitude under the conditions of several alternate signals of the prescribed form.



1 – 5 imp.; 2 – 10 imp.; 3 – 15 imp.; 4 – 20 imp.

Fig. 6. Reduced amplitudes of massif particles dislocation under the conditions of multiple alternations of impulses.

From here it can be seen that along with the increase of impulses number the curve $X_0/A_{max} = f(t)$ goes up towards the abscissa axis, and the curvature radius increases. The compression zone enlarges while the tension zone decreases and then disappears. This is conditioned by the fact that through the course of time the massif is not able to timely recover its static balance. It is obvious that under the conditions of endless increase of the impulses' number the curve tends to move towards the horizontal line. This occasion is inadmissible in practice due to the below conditions.

When the wave from each impulse approaches the disturbance there is particular power injected into the disturbance that under the conditions of permanent volumes increases the pressure and the temperature. Depending on the massif condition the increment of this power may lead to the collapse of the massif and provoke sudden outburst.

References:

17. Kenzhin B.M.: Diss. ... Doctor of Technical Science - M., 1974.
18. Zakharov Y.E. Hydraulic and Electrical Hydraulic Vibrators: Diss... Doctor of Technical Science - M., 1974.
19. Chichinin A.S. Vibration Radiation of Seismic Waves. – M.: Nedra, 1984.