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PRINCIPLES OF VIBRATION IMPACT ON CRACKED METHANE-BEARING COAL SEAM

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Abstract: *The present article deals with the results of research into vibration impacts on a low-permeable coal seam. A method is described of how to create additional systems of cracks for array degassing to ensure its safe preparation. The result of vibration impact of on the coal seam was an increase in internal surface and pore volume of coal. Experimental vibration impacts on the coal seams have shown an increase in its absorption capacity, which ensured the extra impregnation of micro-pore volume of working fluid. With resonance system, the amplitude of the pressure fluctuations may significantly exceed its static value; for its assessment, however, it is necessary to know the characteristics of fluid viscosity, as they will determine the value of this amplitude. A proposed method of vibration impact is used to excite waves in a well filled with fluid, to transfer energy to the coal seam and to create new systems of formation of additional cracks for methane release from remote parts of coal seam.*

Keywords: **Vibration impact, Coal seam, Crack, Methane release, Well, Permeability, Hydrodynamics.**

1. Introduction

The problem of effectively controlled impact on low-permeable coal seam for intensification of methane release from coal is a very current issue. A coal seam should be seen as a typical example of a cracked porous medium. A coal seam always has a block structure caused by the presence of cracks of different origin. The coal seam subjected to hydrodynamic impacts appears to subsequently develop a network of cracks; thus the seam acquires the properties of block-cracked medium. A distinctive feature of such a medium is that the releasing methane is filtered out of the micro-cracks of that part of the blocks; these cracks are artificially created during hydrodynamic impacts in the seam, along the large cracks to the well, and then - via the system of trunk cracks - through the well to the surface (Shcherban et al., 1958). The output of well hydro-impacting in this medium is defined as the permeability of cracks, and the rate of gas release from the blocks. The resulting average size of blocks in the seam is estimated 5-15 m.

The main disadvantage of the method of hydro-impacted coal seams is non-uniform processing of the array associated with on-going use of only basic systems of natural cracks in the coal seam, which significantly limits the number of ways how to avoid sudden outbursts of coal and gas and how to achieve a deep and uniform degassing of coal-bearing stratum. Therefore, apart from advantages, hydro-impacting has significant drawbacks.

The objective of this research is to use vibration impacts as part of a comprehensive impact, joining together and using all the advantages. Vibration impacts combine the advantages of all the above methods, while avoiding their main disadvantages.

2. Results of Vibration Impact on Low-Permeability Coal Seam

The research carried out into vibration impacts on a low-permeability coal seam both via surface wells and also via underground holes showed that this is the way how to create additional systems of cracks for degassing of the array to ensure its safe preparation. The result of vibration impact on the coal seam was

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an increase in internal surface and pore volume of coal. Experimental works related to the impact of vibration on coal seams have shown an increase in its absorption capacity, which ensured the extra impregnation of micro-porous volume of working fluid. This caused the increase of moisture content in micro-porous volume of coal and the subsequent extra desorption of coal-bed methane, which resulted in the increase of depth of degassing in coal seam. The article refers to the results of research into changes in hydrodynamics during vibration impacts on a low-permeability coal seam through a well from the surface. When impacting through the well from the surface, the increase in permeability of the coal seam is evident; this is confirmed by the change in seam hydrodynamics and the increase in gas-releasing surface.

If the system resonates, the amplitude of pressure fluctuations may significantly exceed its static value; however, for its assessment, it is necessary to know the characteristics of fluid viscosity in the well, because in particular they will determine the value of this amplitude.

The proposed method of vibration impact is used to excite waves in a well filled with fluid with the aim to transfer energy to the coal seam to create new additional systems for formation of cracks enabling the methane release from remote parts of coal seam (Ettinger, 1966).

According to this, in the lower part of the well, the conditions are created for resonance and transfer of vibration energy to the coal seam, which ultimately leads to the increase in seam permeability of up to 30-60%, formation of additional (2-3) systems of cracks, and after removal of water from the well, methane is released in the amount of 40-70%.

Laboratory experiments in low-frequency range of 1-100 Hz established that in the initial period of impacting (frequency 10-20 Hz) and in the final period (frequency 60-80 Hz), the activity of methane release from coal samples was low. When coal samples were exposed to vibrations in the range of 30-40 Hz, the methane release is enhanced, a maximum of degassing occurs, which is confirmed by the occurrence of the additional system of coal cracks (Pavlenko, 1999).

At the same time, depending on the frequency and amplitude and on the ratio of these values, a different energy impact occurs, which was established by the intensity and rate of methane release.

It is necessary to mention that the main characteristic of degree of impact on the medium is not the amplitude but the energy of vibrations E and, to some extent, vibration acceleration G, which are proportional, as follows:

$$E \approx A^2\omega^2; \qquad G \approx A\omega^2,$$

where: ***A*** is amplitude of vibrations,

ω is frequency of vibrations.

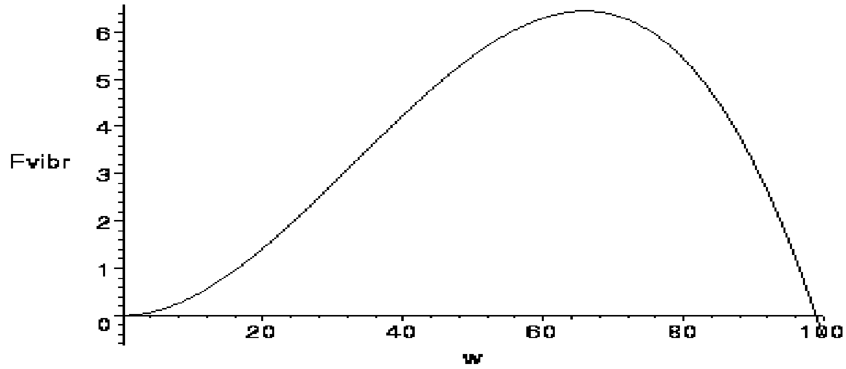
A characteristic of the equipment used is such that the amplitude of the emitted signal decreases with the increasing frequency. This dependence in the specified range of frequencies can be approximated as follows:

$$A = a - b\omega.$$

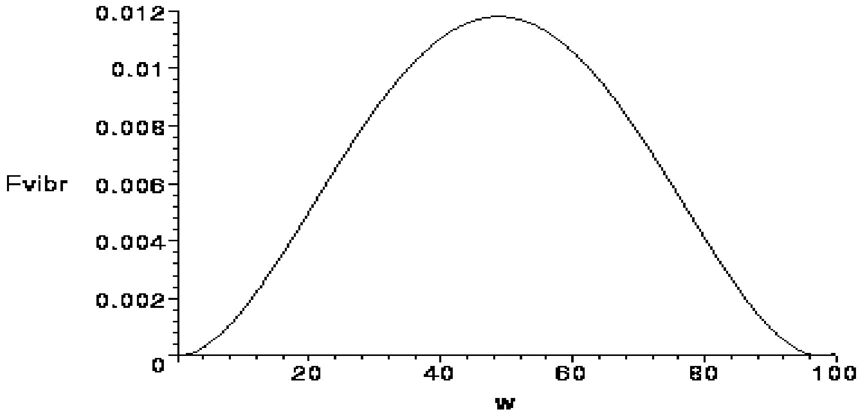
On the basis of experimental data (the triangles in Fig. 1), the coefficients *a* and *b* are equal, $a = -4.6 \cdot 10^{-5}$ and $b = 4.5 \cdot 10^{-3}$ respectively, where *a* is the amplitude independent of the frequency (reference frequency); *b* – the value of amplitude decrease depending on the frequency.

Dependences of vibration energy and vibration acceleration on the frequency are presented in Fig. 1. As follows from these graphs, in the used frequency range, the energy maximum falls on frequencies of order 40 - 50 Hz and acceleration of vibrations is 60-70 Hz.

With the aim to achieve qualitative assessments, it is necessary to consider the simplest model - a coal particle lying on a vibrating base. As noted above, an effective impact requires a separation of coal particles from the surface of vibrating base and their subsequent collision. If this impact is totally inelastic (which fully corresponds to the conditions inside the coal seam), optimum of ***G*** is achieved at maximum difference of speeds in the moment of impact.



a)



b)

Fig. 1: Dependence of: a) energy of vibrations and b) acceleration of vibrations on frequency.

A separation condition is determined by the ratio of vibrating basis acceleration Aω2 and free-fall acceleration:

$$A\omega_c^{\ 2} \geq g\ ,$$

where ωc - critical frequency when the coal is separated from the colliding basis

$$\omega_c = \sqrt{\frac{g}{A}}\ .$$

Accordingly, if the average amplitude of vibrations in the experiments was 3.5 mm, the critical frequency was equal to ω ~ 35 Hz. It is this frequency that determines the lower limit of the range of optimal impact.

As noted above, in relation to coal seam conditions, the existence of resonant frequencies, the impact on which is the most effective, is explained by internal structural changes of coal.

The experiments conducted in this way confirm the increase in the rate of gas filtration in the area of elastic vibrations, which can be explained by the improvement of filtration-capacitive properties.

To summarize, it is possible to state that the conducted experiments confirm the conclusion about a high sensitivity of coal seam to vibration impacts while the response of low-permeable coal seam to vibration impacts essentially depends of the frequency of waves generated by the source.

3. Conclusion

When solving the task of enhancing the gas release from coal, we were allowed to set sufficiently precise parameters for enhancement of methane release from coal depending on the parameters of vibration impact on a low-permeable coal seam. A proposed physical model of the interaction between coal and a vibrating surface qualitatively describes the experimentally observed samples of methane release from coal. Each volume of a coal sample has the optimal characteristics of gas release at a respective amplitude and frequency of vibrations, at which the methane release from coal increases due to vibrations. The basic requirements to enhance the methane release from the coal seam using vibration impacts are to establish a particular relation between the amplitude and the frequency of vibrations, which creates a condition not only for initiation of cracks, but also enables us to preserve them for a given time. The proposed principles of constructing a vibration device to create an effective impact that uses a column of fluid filling the well with the aim to change the status of coal-bearing strata, to increase its intake capacity and, as a consequence, to increase permeability to create gas conductive cracks.

This goal is achieved by the formation of uniform artificial cracks across a vast area of coal seam, by transfer of vibration energy to the "coal-methane" system with a subsequent filtering using the gas conducting cracks united in a single filtering network drilled on the seam through one or a group of underground wells. The area of vast artificial cracks is created by the transfer of vibration energy through the seam underground wells and also by excitation of reflective elastic waves of high intensity in the seam from the lateral rocks of the coal seam. These elastic waves, concentrically propagating from the well along the coal seam, create a uniform network of artificial cracks in the seam. Energy of vibration impact, spreading via a network of cracks in the coal seam, violates the structure of the coal seam, and methane is released from the free and sorption volume that fills the cracks and micro-pores in coal, which is on the same network of newly formed cracks, and is released through the parallel drilled underground well (Rodionov et al., 1976). Therefore, the selection of objects subjected to vibration impact was subordinated to the main purpose of impact – a selection of optimal parameters for vibration impact and, as consequence, for a decrease of high gas content in the processed coal seam.

A proposed methodology of designing the technological schemes for preparation of a mine field, which is based on a comprehensive use of active impact, seems to be a priority alternative for the preliminary preparation as for the sequence and types of active impacts, and the use of degasification wells and vibration impacts in the final stage, leading to an intensive formation of cracks and gas permeability in the coal seam. It is established that methane release from block media of coal seam is conditioned by the development of cracks oriented along the maximal basic system of formed cracks followed by formation of systems of new cracks in the domain of seam hydro-impacting where the rate of gas release and its distribution within the blocks of coal under optimal impact frequencies is estimated by values of the order of 30-40 Hz (Pavlenko, 1999).

Science research-based methodical recommendations have been proposed on the selection of appropriate technological systems to control the gas release through a comprehensive impact. These systems take into account the parameters of a coal seam; this determines a selection of frequency characteristics of the coal seam to ensure the required degree of gas release from the coal seam when preparing the array of rocks, up-to-date speeds of preparatory excavations, as well as a high load on coal slaughtering. A technology of vibration impacts on gas-bearing coal seam has been developed.

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