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FEATURES OF VIBRATION TECHNOLOGY IN THE PREPARATION OF A LOW-PERMEABILITY GAS-BEARING COAL SEAM FOR ITS SAFE PREPARATION

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Abstract: *Vibration exposure is an environmentally friendly and effective method in the technology of increasing the permeability of a gaseous coal mass, which takes into account the resonance in the coal seam when vibrating waves are excited, which in turn helps stimulate the formation of pores and cracks in coals using waves of vibrations generated by low-frequency vibration. In order to study the effect of the vibration frequency and its resonant effect on increasing the fracturing of the coal seam, as well as to study the mechanisms underlying the increase in coal permeability using this method, the final methane output from the coal massif was evaluated as part of the research. During vibration action on a coal massif, the mechanism of cracking and methane release from coal was evaluated using a theoretical review, laboratory experiment and field tests. Research shows that a vibration wave can increase tension in some areas and decrease it in others. In addition to the effect of stress waves in the coal during vibration, it can be argued that this leads to the fact that even a small pulsating pressure creates a better cracking effect in the formation than with conventional static exposure. Assumptions are made about the influence of vibration vibrations occurring at the contact of the vibration emitter with the coal seam, namely, a simple explanation is proposed for the often-observed effect of increased cracking from the frequency of vibration on the gaseous coal mass. the use of vibrators in various designs is not only one of the most effective tools for vibration effects on coal, but due to a number of fundamental advantages over other sources of exposure, they are increasingly being used as a scientific research tool.*

Keywords: Coal seam, Vibration Effect, Methane Recovery, Coal mass, Vbration frequency, Gas permeability, Facturing, Low permeability

1. Introduction

Due to the commissioning of new mines with difficult physical and geological conditions, as well as the deepening of mining operations, the problem of increasing the methane recovery coefficient for coal reserves under development in deposits of this type is gaining considerable weight and urgency. The interest in this subject is due to the need to solve a number of problems, among which the problem of removing the gas barrier during coal mining occupies a special place. Solving this problem certainly requires a more thorough theoretical and physical analysis of the processes occurring during methane recovery from low-permeability coal seams and an increase in the methane recovery coefficient. During the operation of coal deposits, numerous and constantly improving methods of increasing methane recovery from coal seams are used, as well as the use of modern technological schemes for preparing coal seams.

2. Setting the task of obtaining the optimal vibration frequency

The idea of using vibration effects on the coal mass appeared due to the difficulties of extracting methane from a low-permeability coal seam. By that time, we already knew something about the unusually high sensitivity of the coal massif to vibration effects and changes in its stress state. In laboratory experiments and in full-scale (field) conditions, the existence of a relationship between vibration parameters (frequency, amplitude) and gas emission has been established, which makes it possible to predict the success of coal seam treatment and optimize the process of their implementation in specific conditions.

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The result turned out to be positive: a distinct effect of vibration action on the mode of changing the gas output from coal was found (Pavlenko, 2004), Experience has shown that it is advisable to use vibration effects to increase methane recovery from a coal massif at certain frequencies.

3. Case study of the task

Increasing the permeability of the coal seam to increase methane recovery from a low-permeable coal seam has always been the main focus of research in the field of combating gas emissions into mining, as well as the development of coal seam degassing technology and associated methane production.

Depending on the ratio of frequency and amplitude, a certain range of vibration efficiency has been established for a low-permeability coal massif, which determines the transition to a state in which the separation process of the «coal+methane» system takes place. For optimal vibration action, it is necessary to transfer energy to coal aimed at the internal structure of coal, its restructuring, which ensures the correct technology of vibration action on the coal seam (Pavlenko and Ivanov, 2021). It is in this case that the vibration energy with maximum efficiency leads to the destabilization of the «coal-methane» system, since all the energy released during inelastic vibrations is used to release methane from the porous-fractured coal mass (Pavlenko and Mikhailov, 2002).

4. Technology of methane extraction from coal using vibration

Therefore, practical studies of ensuring effective degassing of a low-permeable methane-bearing coal seam using vibration action on the array cannot be solved without the use of modern technological schemes for influencing the coal mass. It can be argued that in this case, after vibration action, maximum methane release from the coal mass is observed and, according to forecast data, the residual methane content of treated coal decreases from a content of 30-40 m3/t to a safe level of 1.5-2.5 m3/t, which will ensure safety in the preparation and development of the coal seam. One of the variants of the vibrator design is placed in a well for vibration action on a coal massif in order to increase gas-conducting cracks in a low-permeability formation, creating a flow of vibration energy in the massif (Fig.1).

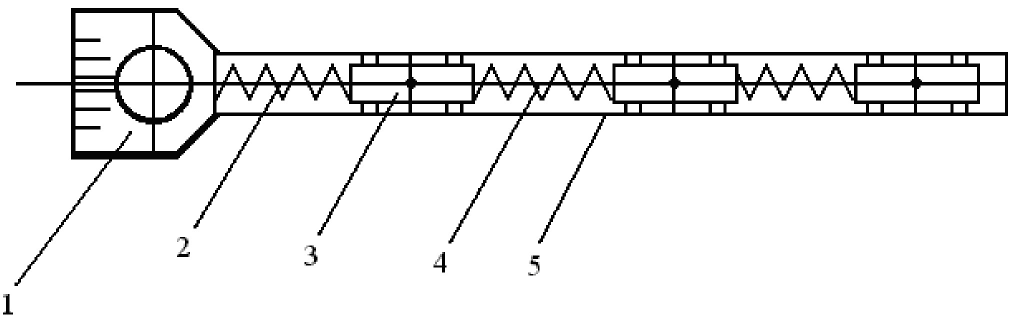

Fig. 1: Construction of a vibrator in a reservoir well to create a vibration effect where: 1 denotes the vibrator; 2 - damping spring; 3 - debalance; 4 - centering rod; 5 - the walls of the vibration well.

The existing problem for using vibration effects on a low-permeability coal seam can be considered as a dynamic system (vibrator + coal array) as a set of concentrated masses and elastic elements (Fig.1). These results generally lead to the fact that when studying the vibration frequency on a model, in order to coordinate with experimental data at a production facility, it is necessary to evaluate the parameters of the latter, which obviously dramatically increases the predictive value of such a mode. In terms of the complexity of gas recovery from a coal seam with a high methane content and low gas permeability, the study examined the effects of a stress vibration wave in coal using a theoretical review, laboratory experiment, and field tests. The study shows that vibration waves can increase tension in some areas and decrease it in other areas.

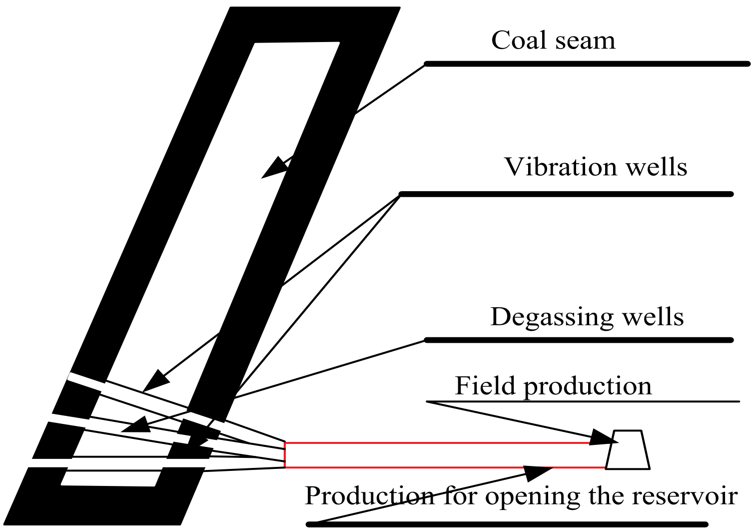

Fig. 2: Technology of vibration action of steep converging formations by wells drilled from capital workings

Solving the problem of methane recovery certainly requires a theoretical and practical analysis of the processes occurring during vibration action on productive layers of a low-permeable coal massif to degass the massif and increase the methane recovery coefficient. In addition to the effect of vibration in the coal mass, it can be assumed that this effect leads to the fact that even a small pulsating effect on the coal mass creates a better methane release effect than with conventional static exposure. Based on the research, a vibration technology has been proposed for a low-permeability coal seam to improve permeability and increase methane recovery (Fig.2.). Experimental research is dominant here, although it is implemented by trial and error. However, the evolution of the appearance of cracks and pores in the coal mass during vibration is clear, especially when the forced vibration frequency coincides with the natural frequency of the formation, which causes the phenomenon of resonance. Therefore, in order to increase the permeability of gas-bearing coal seams and increase the efficiency of methane recovery from it, vibration action on the formation is proposed as a new method of exposure.

5. Evaluation of the technological scheme of vibration generation for gas-fired coal

The results showed that vibration action on a coal gas-saturated coal seam has a high ability, which reduces the residual methane content to the level of 60-70% of the initial methane content of the coal massif. Assessing the effect of vibration on the coal-methane system, it can be assumed that vibration in the low frequency range (1-100 Hz) on a low-permeability coal seam leads to a gradual change in the state of the coal massif, which determined the increase in fracturing and methane release from the coal seam in the vibration zone. The experiment showed that in the frequency range of 12-14 Hz and 30-40 Hz, vibration action leads to the separation of the coal+methane system with the transition of methane to a free state and is removed from the array by degassing, which indicates the presence of resonant frequencies contributing to the formation of new crack systems in the formation. High efficiency of vibration action by elastic vibrations on a coal massif is achieved through wells from underground workings, under rational modes of action, taking into account the characteristics of the coal seam being worked and taking into account the tasks set. At the same time, the rate of methane filtration through cracks and pores in a low-permeability coal seam is a critically important property for gas production. An increase in methane recovery during vibration action serves as a predictive factor for assessing the permeability of a coal massif as a fractured-porous medium. The complete controllability of vibration effects on the coal massif in comparison with other effects is obvious, and an assessment of the actual capabilities of the vibrator as a source of vibration action becomes very relevant. The results of vibration experiments show that vibration affects the formation of new crack systems that change the characteristics of the coal arrays being developed. The change in the characteristics of coal during vibration in the blocks indicates that there is an increase in the concentration of cracks and pores in the coal, which consequently leads to intensive methane release from the coal block. At the site of vibration action in the formation, an unloaded zone is observed, a zone of increased gas drainage, which is associated with the formation of increased fracturing and, as a result, permeability, which leads to increased degassing of the formation, the issue of safety is being resolved, and therefore the technology for preparing a low-permeable gas-bearing coal seam, planning decisions are being made for the enterprise: the length of the excavation pillars increases, the speed of movement increases the face and the load on the cleaning face (Ruban et al., 2009a; 2009b).

6. Conclusions

During vibration action on methane-bearing coal, intense methane release is observed, this is due to the formation of new and expansion of natural cracks in the coal seam, as well as internal structural micro-fractures affecting the gas output from coal. The energy of the vibration effect on the low-permeability coal seam in the bottomhole zone is used to create additional new crack systems. This impact is sufficient to make significant changes to the state of the coal-methane system and divide it into its components. We analyze the effect of vibration on an increase in methane release associated with the formation of new crack systems in a coal seam using modeling results and field experiments. The main difficulty of practical research is that in real conditions coal seams are very diverse in their properties and represent a complex heterogeneous structure. The result concerning the dynamics of the interaction of a vibrating source with a coal seam indicates the changing nature of this interaction. Filtration processes occurring in low-permeability coal seams during vibration are extremely complex, therefore, when studying methane release from a coal seam. Experimental and theoretical directions are distinguished. Therefore, a production experiment always performs a dual role: it serves to determine some closing relationships of a mathematical model and to verify the correspondence of a mathematical problem to a real physical process (Wilke and Pavlenko, 1999). Therefore, the study, in the process of experiments on vibration, allows us to predict the course of its course and the consequences of physical influence on the methane-bearing coal seam in real conditions. This makes it possible, in particular, to reduce the risk when making management decisions on the impact on the coal massif.

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