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DEGEREE OF SUSCEPTIBILITY OF THE GAS-BEARING COAL MASSIF TO CHANGES UNDER VIBRATION AND TECHNICAL SOLUTIONS FOR INCREASING METHANE EXTRACTION FROM THE RESERVOIR

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Abstract: *Application of the vibration effects for effective preparation of a low-permeability coal seam is a promising process, which requires to be continuously improved. The main difficulty of the theoretical research in this area is that the coal seams are very diverse in their properties and represent complex environment. During the vibration action, their volume and filtration characteristics change, which leads to the change of the massif structure and amount of the pore-crack space in the coal. This effect can be controlled.*

Keywords: Coal mass, vibration impact, permeability, methane, impact array, microcracks.

1. Introduction

Destabilization of a coal massif caused by vibration of the formation is highly sensitive to changes of external factors (Asomov, 1960). Control of the process parameters is crucial for increasing methane recovery from the reservoir. The discussed method estimates spatial variability of the vibration and identification of the directional variability of the coal massif properties. A great interest in technologies for increasing fracturing in the coal massif has formed the research direction.

Considering this effect, it is possible to choose a proper frequency and amplitude of the vibration process acting on the formation, which leads to the growth of cracks in low-permeability coal (Jia et al., 2012). Despite a large amount of experimental information, the degree of susceptibility of the coal massif to changes of the vibration parameters and the wave propagation in the coal seam remains poorly understood (Pavlenko, 2022). The phenomena occurring both in pores and in micropores of a low-permeable coal massif have not been sufficiently studied by experimental methods, yet. At the same time, it is necessary to pay a special attention to the problematic areas of the coal deposits in promising fields considering the technical possibilities.

2. Technological solution

The research focuses on the mechanism of vibration action at frequencies that induce resonance in the coal seam and ensure creation of the most favorable conditions for emerging new crack systems, which makes the stable methane recovery from the coal massif possible. Accomplishing the process requires to build up the proper organizational procedures.

The procedure concerning increase of methane recovery from a low-permeability coal massif consists in a sequence of technological solutions and means with the goal to ensure maximum purposefulness and effectiveness of the process. The key factor, which follows preparation of the coal seam for safe and effective exploitation, is the type of management activity reflecting a set of priorities playing the role in formation of the impact on a low-permeable gas-saturated coal massif. Next, using vibration of the low

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frequency range is investigated. Organization of the management decisions is determined primarily depending on geological conditions of the underlying reservoir and on the vibration parameters, which are also important.

Initially, the experimental studies of the vibration effect on the K-2 gas-bearing coal seam of the Victoria mine in Donbass were carried out using the underground vibration wells in the frequency range from 1 to 100 Hz. The resonant frequencies, at which the maximum cracking and gas release from the coal massif was observed, were determined to 7–14 Hz.

Fracturing and gas permeability of a coal massif are characterized by two different states. It was found that the response of the coal massif on the vibration action is appearance of new cracks and their branching in the form of the blocks (Fig. 1).

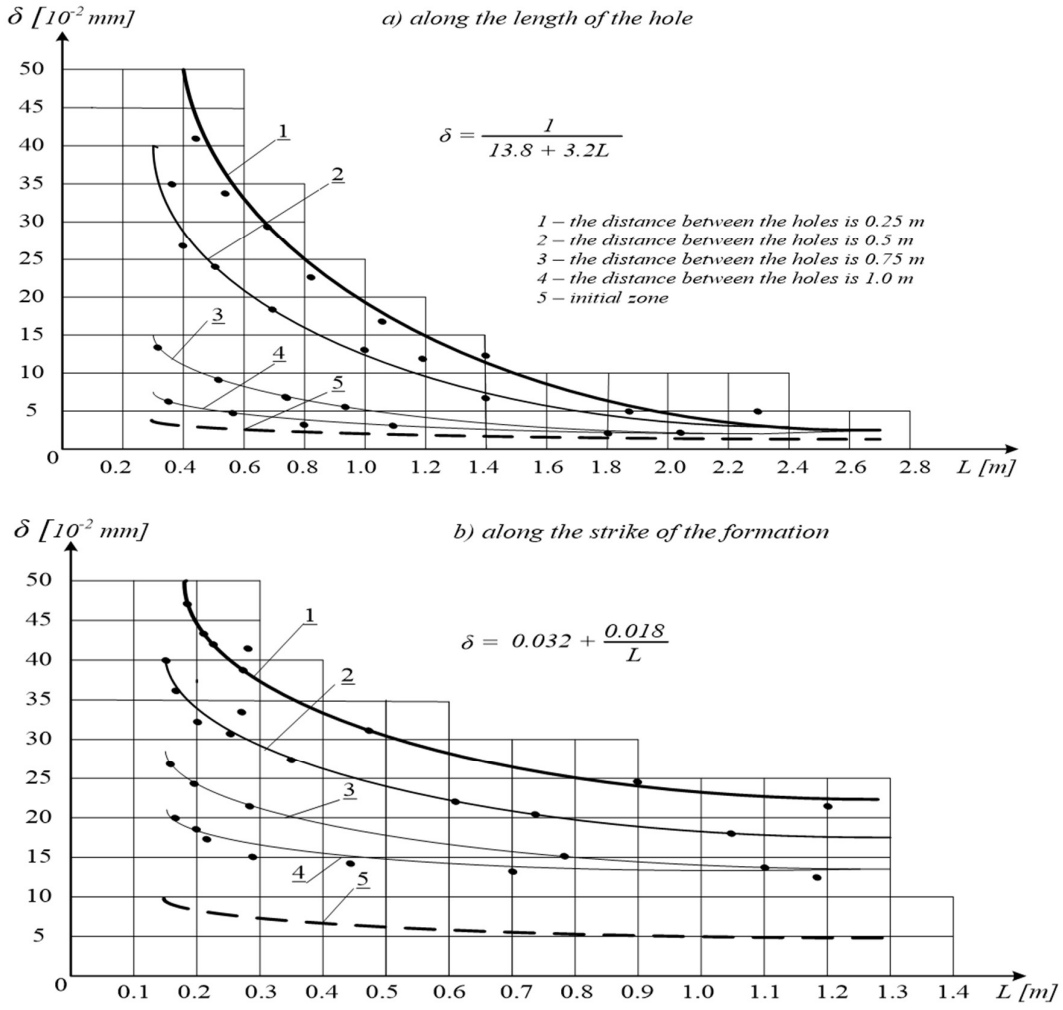

Fig. 1: Nature of changes in the gaping of microcracks of the K-2 formation of the Victoria mine in Donbass from the length of the hole during vibration.

The conducted studies in the field of the Victoria mine in Donbass were aimed at investigation of the nature and rate of the gas recovery during the transition from the zones without and with the vibration treatment.

The results show a clear difference in the process rate if the new system of cracks appears. The study shows that the vibration effect increases diffusion and filtration permeability of the formation by 3–5 times and the degree of permeability and softening of the array rises as well as the gas-releasing capacity. It leads to the conclusion that the new crack systems in the impact zone allow methane to be more intensively drained from the coal bed and ensure successful degassing of the treatment site (Fig. 2). The study also confirms

the assumption that it is possible to achieve a directional change of the coal seam properties (e.g. the massif permeability) leading to increase of the gas recovery.

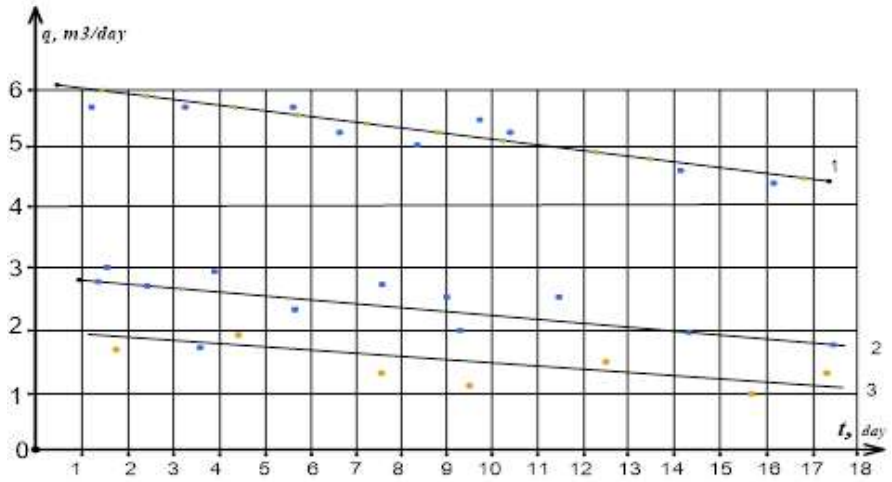

Fig. 2: The rate of gas recovery of the K-2 formation into the holes in the vibration area.

Further research is required in the field of the vibration technology. The study will focus on application of hydraulic vibrators (Fig. 3) whose principle of work is based on generation of pressure fluctuations that propagate in porous medium filled with liquid and lead to occurrence of new systems of cracks and microcracks in the coal massif and to destruction of its spatial structure. The working fluid makes the vibrator barrel to rotate providing the pulse frequency from 10 to 150 Hz and the pressure amplitude from 1 to 10 MPa. The cone reflector focuses the generated pulse, which increases impact of the transmitted energy on the formation.

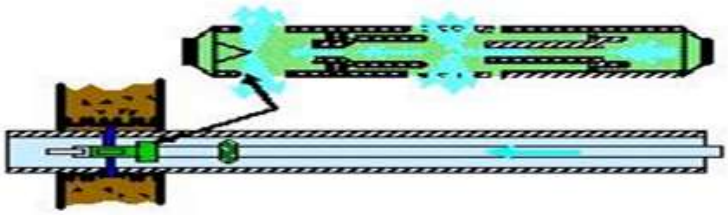

Fig. 3: Hydraulic vibrator in a coal seam.

The fluctuations of the pressure generated by vibrators spreading in the porous medium and fluid reservoirs give rise to new systems of cracks and microcracks in the coal massif and to destruction of its the spatial structure. The mobility of the water-methane interface increases, the surface tension of the liquid at the boundary with the solid surface decreases, and the rate of capillary impregnation of water in the coal structure rises. The pressure fluctuations in the flooded reservoir contribute to intensification of the coal impregnation processes, which leads to increase of the absorption capacity of the hydraulic injection wells and to appearance of a new crack system.

The technological scheme of the vibration device in a coal massif intended for experiments corresponding to the technological solutions for preparing a gas-bearing coal massif for intensive mining is shown in Fig. 4.

On one hand, the vibration, which is a part of the destabilization process of the coal massif, is affected by external conditions and factors. On the other hand, the methane release from the coal seam has its own dynamics, which provides different possibilities for maintaining stability of the process.

The scientific concept of destabilization in the coal-methane system consists in action of external active factors, namely vibration.

At the same time, the vibration effect of the coal massif is induced both through the surface and underground wells, which influences the process of intensification of the methane recovery. These vibration effects are going to be considered in the next stage of the study related to increasing permeability under the influence of the vibration sources.

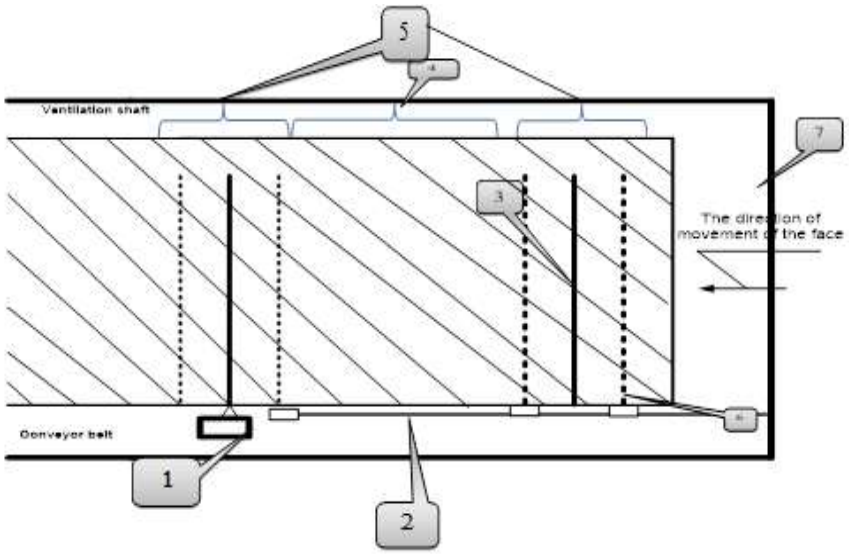

Fig. 4: Scheme of vibration action on the coal seam through underground wells: 1 - vibration oscillator; 2 - degassing pipeline from degassing wells; 3 - vibration wells; 4 - comparison zones (length 300–400 m); 5 - vibration treatment zones of coal seam; 6 - formation degassing wells; 7 - mounting chamber 10–20 m long.

According to the results of the field studies conducted in the mine field, the vibration method is an effective one of exposure. It leads to increase of the methane recovery in the zone of fractured coal forming a block of massif of low-permeability coal seam. The excavation is done at certain frequencies close to the formation resonant ones. If the natural frequency of the coal-liquid system coincides with the frequency of the field vibration, then the resonance occurs, and the energy of vibration is transformed to kinetic energy of the liquid in the formation, which leads to development of cracks.

3. Conclusions and discussion

The paper examines patterns of fracturing under vibro-wave action in conditions of heterogeneous state of stress of a coal seam before formation of the additional crack systems during in advanced prepared coal massif. From a scientific point of view, it is important to understand why the penetration of the pressure waves into the coal seam leads to increase and intensification of the methane recovery from the coal mass. A vibration method is proposed to ensure structural disruption and formation of additional systems of gas-conducting cracks in a coal seam. Its efficiency depends on the vibration frequency, considering the resonant ones of the array of fractured blocks. This predicts intensity of methane extraction from coal.

The specified method increases impact on the formation, which depends on the power of the used vibration source. The further development of the vibration method leads to increase of its efficiency in the field of degassing. The process does not depend only on the intensification factors, but also on meeting the requirements of the correct choice of active exposure technology. The process of increasing magnitude and number of the crack openings during the vibration is achieved not only by the frequency of exposure, but also by the time of action on the coal massif. This is utilized in the pore space.

It should be noted that in this case the wave pulse completely produced by the vibratory device causes changes in the coal massif. Consequently, the vibration in the coal seam causes changes in the stress-strain state of the array, which has additional effect on the permeability and porosity of the array.

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