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THE FORMATION OF ZONES OF THE COAL ARRAY VOLUMETRIC IMPREGNATION AS A RESULT OF THE VIBRATION IMPACT

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Abstract: *This article deals with the application of vibrations and hydraulic impacts exposing the low-permeability coal seams with the aim to increase the capillary impregnation and the volumetric saturation of the micropores. This technological procedure contributes to increasing the gas recovery from a coal array. The method of vibration exposure utilizing the boreholes leading from the surface is new. It applicability was tested at a mine site. The results confirm its effeciency in creating new systems of gas-conducting cracks. The results of empirical calculations and industrial experiments confirm the possibility of its application for increasing the permeability of the deep coal layers and their saturation with liquid. The obtained results are described and commented. The development of an appropriate physical model of the studied phenomenon, its refinement, and development of the adequate mathematical tools are in progress at present time.*

Keywords: Vibration, Capillary, Crack, Gas drainage, Installation, Impregnation, Methane, Liquid movement.

1. Introduction

The aim of this article is to study the influence of the vibration exposure on deep coal layers concentrating on the increase of their volume saturation. The idea of using the vibration effect comes from the low permeability of coal and low gas recovery of the coal seams. The paper is focused on working out the principal rules and recommendations for timely preparation of the coal seams originating from the practical experiments, which were carried out in the coal seam field of the mine of "Komsomolskaya" belonging to JSC "Vorkutaugol" (hole no. 4447).

2. Analytical solution

The hydraulic pressing of fluid in the coal seam through the bore from the surface is an important stage of timely preparation of the field for the safe and effective excavation. Enlarging the width of the cracks is achieved by changing the fluid flow regimes in the open fractures and in the pore space. Comparing with other ones, the method of vibro excitation increases the saturation of the coal seam several times, which is enabled by utilization of the capillary effects.

The purpose of the vibration exposure through the bore from the surface is to increase the flow rate of the fluid in the capillaries due to the alternating forcing effects and to rise the volumetric saturation of the coal array, in general.

An important step of the research is the determination of the saturation velocity of the liquid permeating in capillaries. The calculation of the steady state volumetric flow rate V is given by the Poiseuille's equation, which reads

$$V = \frac{\pi r_k^4 \Delta P}{8 \mu l} \tag{1}$$

r_k is the radius of the capillary, l is its effective length, μ is the viscosity of the fluid flowing through the capillary, and ΔP is the pressure gradient.

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Fig. 1 shows the vibration impact on the changes of the fluid flow rate in the borehole drilled in a reservoir. *ΔH* denotes the relative decrease of the water level, OA is the decrease of the hydrostatic pressure, AO* is the refilling water height in the well, O*B is the period of the vibration (λ = 3 – 6 cm, ω = 4 – 6 Hz), *C* is the demotion of the oscillations, and СД is the stabilization level.

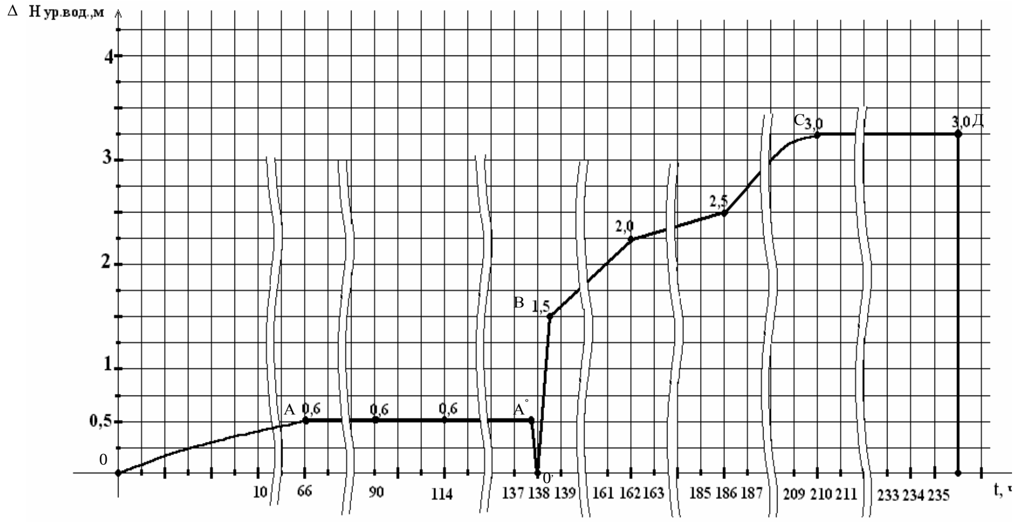

Fig. 1: The hydrodynamics phenomena in the period of the vibration exposure of field mine.

The analysis of the obtained experimental results enabled to identify the main ways leading to increasing the coal array capillary impregnation. To induce the oscillations of the liquid, the machine producing alternating excitation was applied. Its principle is shown in Fig. 2.

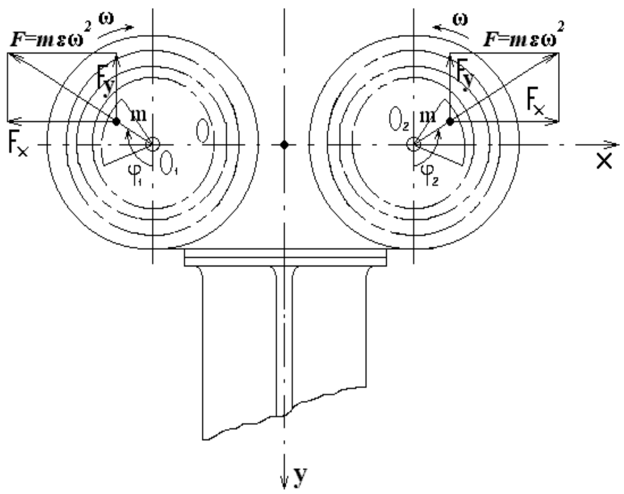

Fig. 2: Self-balancing vibration exciter of directed oscillations.

The oscillation amplitude as given

$$x(p) = \frac{m_0 e p^2}{c - (M + m_0)p^2} \, . \qquad (2)$$

To find the optimum amplitude and frequency of the excitation, the data recorded in well No. 4447 drilled in a low-permeability and high gas-bearing formation were utilized.

The alternating dynamic effects, which drive the fluid in the bore, were induced by rotation of the eccentrically situated weights mounted on a platform. Therefore, the excitation pressure amplitude *F* is a harmonic function of time

$$F = m l \omega^2 \sin(\omega t) \, . \qquad (3)$$

ω is the angular speed of the rotation, m is the mass of the eccentric weights and l is the weights eccentricity.

The vibration tests made in the well enable to predict the absorption characteristics of the fluid.

3. Results and discussion

The liquid flow through the capillaries depends on the capillary pressure $P_к$, which is a function of the contact angle α between the liquid surface and the capillary wall, the liquid surface tension σ, and the capillary radius r

$$P_k = \frac{2\sigma\cos\alpha}{r}. \tag{4}$$

If the capillary is situated in the horizontal direction, the influence of the liquid hydrostatic pressure is insignificant on its flow. For other cases as shown in Fig. 3, the hydrostatic pressure must be taken into account. Its magnitude is given by relation (5)

$$P_h = \rho g l \sin\alpha \tag{5}$$

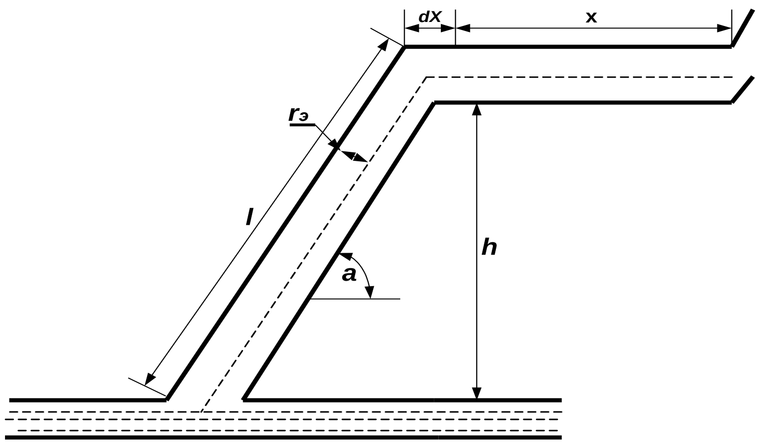

Fig. 3: The layout of the arbitrarily oriented capillary in the coal array.

The volumetric flow rate of the liquid through the capillaries the shape of which is uneven is governed by relations (6) and (7)

$$V = \frac{\pi r_k^4 (\rho_F - \rho_G)}{8\mu}, \tag{6}$$

$$V = \frac{\pi r_k^4}{8\mu}\left(\frac{2\sigma\cos\alpha}{r_k} - \rho_F g l \sin\alpha\right). \tag{7}$$

r_k is the effective capillary radius.

It is difficult to find out the capillaries effective radius and the contact angle α because their values cannot be determined by direct measurements. Therefore, to simplify the problem one of the quantities should be excluded utilizing that the liquid in the capillary rises to the height of $H = l \cdot \sin\alpha$ during the coal wetting.

In the case when the capillaries are located horizontally in the coal array, then the hydrostatic pressure has no effect on the fluid flow velocity. Then it holds

$$\frac{\mathrm{d}l}{\mathrm{d}t} = \frac{r_k \sigma \cos\alpha}{4\eta l} \tag{8}$$

The same consideration is used to describe the flow rate in the capillaries driven by the methane

$$V = \frac{r_k \sigma \cos\alpha}{4(\eta_1 l_1 + \eta_2 l_2)} \tag{9}$$

where l_1, l_2 are the lengths of the capillary filled with the liquid and the methane, respectively, η_1 and η_2 are the liquid and methane viscosities, σ is the surface tension at their boundary, and α is the contact angle at the border between the liquid and the gas.

4. Conclusion

The carried out research on the vibration exposure to the low-permeability coal massif presented in this article has not been terminated yet. The achieved results can be considered as one of the stages dealing with this important problem in the mining industry. The author expresses his gratitude to all persons who took part in accomplishing the industrial experiment.

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