Technology and means of a coal seam interval hydraulic fracturing for the seam degassing intensification

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Abstract. Interval hydraulic fracturing use for the seam degassing intensification actuality is explained. The known methods of degassing are reviewed. Technological scheme of the interval coal seam hydraulic fracturing implementation is worked out. The equipment to fulfill degassing intensification measures is suggested.

Coalbed methane can be recovered from subsoil independently from coal extraction using gas production technology subject to its profitability both as the associated mineral product (methane production) and in degassing process aimed to provide safe labor conditions (methane safety). The latter case makes possible to intensify mining performance, that is, to increase the rate of heading and to increase the coal extraction face output [1–9]. For this reason, there is a paradoxical situation in the coal industry, when the technical abilities of coal extraction at flat seams increase a few times an allowed extraction rate limited due to the gas factor. We must underline at once that we do not consider the industrial methane extraction with, for example, the USA technology, which allows suggesting that degassing is combined with commercial methane production from coal seams [10, 11]. But it is known that in conditions of San Juan basin (this is the basin where 95% of coal seam methane is extracted and their experience is cited by all researchers) gas extraction from the thickest Fruitland coal seams was due to a very high permeability conditioned by the seam cleat nature, so it is practically coal and gas deposit.

From all known time-related degassing methods [3, 5] we can mark out three types: the early one done before the mining work; the preliminary degassing of the worked out seams and the current degassing from the boreholes drilled from underground openings or from the surface. At present at Russian mines they use degassing of a seam under work from preparatory openings (ventilation or conveyer galleries) in every 15–20 m. Still at the seams with low permeability this technology does not give the necessary degassing level. Using the existing degassing methods in Russia they extract from 20 to 30% of the total volume of methane emitted. Due to the small volume of degassing work and the lack of effectiveness of degassing schemes in many gassy mines of Russia the gas barrier to achieving high speeds of the working heading and high output from extraction faces is retained [19].

A further increase in efficiency, technical and ecological safety of underground mining of highly gassy coal deposits are inextricably linked to the development of special measures and artificial methods to stimulate gas recovery from not unloaded coal seams.

The filtration ability of the coal seam is determined by the number, spatial orientation and absolute permeability of its cracks, through which the free methane can move in the filtration mode. To date,
the only industry proven way of a coal seam stimulation in order to increase its gas recovery is the seam hydraulic fracturing (GRP) from the surface—the way is not controlled, time-consuming, expensive and it requires a considerable investment of time (up to 3–5 years and more) for a single borehole development. Besides, in order to provide the degassing efficiency of about 50% the period of gas extraction from the seam should be 7.5 years and to achieve efficiency of 60%—10.8 years, and so on.

Given that 90% of methane contained in coal seams is in the adsorbed state, so in order to bring it out of this state it is necessary to impact on the coal seam so that active methane separation would happen. The existing degassing methods when degassing boreholes are drilled from the surface or from underground openings shows that through the borehole walls of the well gas from a very small area of the coal seam in the vicinity of the borehole is released.

Attempts to borrow the known fracturing technologies from oil production face a number of difficulties. Unlike petroleum industry, coal production usually requires the creation of cracks in a direction substantially not coinciding with the direction of the main compressing stress action (for example, inclined plane). To intensify the degassing processes an original way of vibration exposure from the surface of a special vibration sources has been proposed [12, 13], tested on the uranium deposit. Gas releasing ability of not unloaded coal seams can be increased by improving their reservoir properties based on interval hydraulic fracturing method (Figure 1), one of the variants of this idea was presented in [14].

![Figure 1](image_url)

Figure 1. Technological scheme of coal interval hydraulic fracturing: 1—putting the packer into the borehole; 2—sealing of the borehole; 3—hydraulic fracturing of coal; 4—depressurization of the borehole and advancing the packer.

Particular importance is attached to design of the between-the-packers control valve that supplies working fluid for the borehole and two sides sealing and subsequent disruption of the coal seam in the sealed borehole area. Moving packer along the borehole one can make hydraulic fracturing with water or some water solutions at the specified sections of a coal seam. Balanced packer with a new type
control valve allows increasing the reliability of sealing on both sides. To implement the coal mass fracturing technology a double sided packer is developed, allowing to carry out the interval hydraulic fracturing (Figure 2).

**Figure 2.** Fracturing device and a coal borehole simulator: 1, 2—elastically expanding sleeve, 3—between-the-packers control valve, 4—locking end cap, 5—connecting coupling; 6—coal borehole simulator; 7—gauge.

The fracturing device includes two elastically expanding sleeves 1 76 mm in diameter, between them a between-the-packers control valve 2 is installed necessary to control the working fluid in the fracturing device hydraulic system. It serves for timely packing the borehole in the zone between the elastically expanding sleeves and for further pressure increase in this area to the value sufficient to fracture the coal massif.

Between-the-packers control valve (Figure 3) consists of a shallow case constructed as a cup 1 with holes 2 for the working fluid passage which is connected to the open part of the hollow hub 3 by means of threads. At the ends of the case elastically expanding sleeves 4 and 5 are fixed which can change their form under working fluid pressure action. Inside the case near the cup bottom a sealing bushing 9 is attached with the spacer 8, wherein the spool 10 is placed and its central opening contains a hollow tube 11 mounted between the bottom of the cup 1 and the end of the hollow hub 3.

In the walls of the sealing bushing 9 there are radial holes 12 axes of which coincide with the axes of the holes 2 in the walls of the cup 1. Pressing spool 10 to the end of the sealing bushing 9 is performed by a spring 13 mounted between the spool 10 and the bottom of the hub 3. At the ends (from the cup bottom side 1) of the spool 10 and hollow tube 11 there are hollow spline slots 14 and 15, respectively. Sealing spacers 16–18 in the hollow hub, at the spool 10 and in the sealing bushing 9, respectively, provide sealing of all the device connections. The surface of the sealing bushing 9 hole is lapped along the outside diameter of the spool 10, which also provides sufficient connection sealing.
Figure 3. Between-the/popper control valve.

The device works in the following way. Through connection 7 the hydraulic fluid is supplied under pressure to the device, where it acts on the sealing members 4 and 5, increasing in diameter and pressing them against the walls of the borehole—so sealing of its portion occurs. When the pressure to which the spring 13 is adjusted increases, spool 10 starts moving to the hollow hub 3 which provides access to the radial holes 12 and 2 in the walls of the sealing bushing 9 and the cup 1 through which the working fluid enters the sealed space of the borehole. After hydraulic fracturing is done the working fluid pressure is reduced and spool 10 under action of spring 13 returns to the initial position and elastically expanding sleeves 4 and 5 get the initial shape.

Studies of the fracturing device working modes through a between-the-packers control valve were carried out on the test bench (Figure 4).

Figure 4. Test bench for testing technologies and tools for a coal seam interval hydraulic fracturing.

The test bench consists of a piece of a pipe 1 imitating the rock massif borehole. The pipe 1 with the inner diameter 80 mm has a gauge 2 and a ball cock 3. Fracturing device 4 inserted into the pipe 1
is connected to the pump station 5 with a pressure pipeline. The pressure pipeline is equipped with Stauf DM-750 flow meter made in Germany with 16 l/min capacity at 32 MPa pressure.

Tests were conducted in the following sequence. The fracturing device 4 was inserted into the pipe 1 in such a way that between-the-packer pressure valve was in the area of the gauge 2 and ball cock 3 installation. Then with the ball cock 3 closed, working fluid under pressure was pumped from the pump station 5 through high pressure pipeline with the flow meter 6 to the fracturing device 4. When the pipeline pressure reached 7 MPa (according to the pump station gauge), pressure in pipe 1 in the area of between-the-packers control valve location also started increasing that was recorded by gauge 2. That meant the fracturing device elastically expanding sleeves isolated the area where the between-the-packer control valve was located and the spool spring 4 (Figure 3) adjusted for 7 MPa compress and allowed the spool 10 working fluid under pressure bypass to the between-the-packer area.

The maximum working fluid pressure in the between-the-packer area recorded during the test was 16 MPa. There was no fluid leakage around elastically expanding sleeves. The second stage the fracturing device test was conducted to determine the uniformity of the working pressure distributor during the working fluid pumping into the between-the-packer area.

At that time the ball cock 3 (Figure 4), was opening which provided hydraulic fluid free release from between-the-packer area to the surface. Then working fluid was pumped to the fracturing device 4 from pumping station 5 along the pressure line with the flow meter. The amount of working fluid was recorded by the flow meter and the pressure—by a pumping station gauge.

When the pressure in high pressure line was achieving 7 MPa the working fluid was released from between-the-packer area through the open ball cock. That meant the fracturing device elastically expanding sleeves isolated the area where the between-the-packer control valve was located and the spool spring adjusted for 7 MPa compress and allowed the spool to bypass the working fluid to the between-the packer area and further through a ball cock to the surface. The speed of fluid flow through three openings 4 mm diameter in the between-the-packer control valve case was 6.5 l/min. The tests proved that there were no working fluid leaks through elastically expanding sleeves when the fluid was released to the between-the-packer area. In Figure 5 the pressurized hydraulic system pressure change graph is presented depicting the process of working fluid release through between-the-packer control valve.

![Figure 5](image)

**Figure 5.** Character of pressure pulsation in the process of working fluid release through the between-the-packer control valve.

The graph shows that pressure fluctuations in the process of the working fluid release do not exceed 0.5 MPa. This slight pressure variation will not affect the reliability of boreholes sealing with elastically expanding sleeves, which are used in a fracturing device.

The proposed technology can be implemented according the following scheme of oriented interval fracturing for gas emission intensification process of methane into degassing boreholes and technical means for its realization (drills, pumping stations, packers) (Figure 6) [15–18]. It allows to avoid the dynamic phenomena in the mines and also to provide safe and efficient work of a coal
extraction face with high output. For drilling and interval hydraulic fracturing the drill SBR-400 or SBU-300 is chosen as both have automatic drilling rod replacement without idle running and fast rod returning which increases the work efficiency due to vast time reduction of hydraulic fracturing measures execution.

Figure 6. Technological scheme of methane degassing intensification with interval hydraulic fracturing through a degassing borehole.

Conclusion
As a result of the work is expected to create a technology basis for degassing borehole drilling work amount 3 times reduction while increasing the intensity and depth of coal massifs degassing not less than 2 times with the output of methane-air mixtures. Achieving these parameters will allow:
- to increase coal mining safety by increasing the depth of its degassing and reduce the risk of sudden methane outbursts;
- to increase coal mining safety due to outbursts danger reduction with partial unloading of rock massif from stresses using hydraulic fracturing cleats;
- will allow to reduce the amount of degassing boreholes drilling;
- will reduce harmful emissions of methane into the atmosphere.

The laboratory tests proved: fracturing device seals safely between-the-packer area and can be used at interval hydraulic fracturing of coal massif;

Between-the-packer pressure control valve provides timely thrust of elastically expanding sleeves and performs pressurized working fluid supply to the packed area.

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