Development of technical means for directional hydraulic fracturing with shearing loading of borehole walls

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Abstract. During the process of mineral deposits’ mining one of the most important conditions for safe and economically profitable work of a mining enterprise is obtaining timely information on the stress state of the developed massif. One of the most common methods of remote study of the geomechanical state of the rock massif is hydraulic fracturing of the formation. Directional hydraulic fracturing is a type of the method employed to form cracks across production wells. This technology was most widely used in the gas industry to extract gas from shale formations. In mining, this technology is used to set up filtration screens, to integrate degassing, to soften the hard roof of coal seams. Possible practical appliance is the expansion of the application field of this technology to intensify the production of viscous oil, to leach non-ferrous metals, to create in the rock massif anti-filtration screens for various purposes, as well as to measure stresses acting along the wells.

Known methods of lateral cracks’ formation are based on the use of gap initiators created by jet or mechanical slitters. This approach has no alternatives for cased gas and oil wells. However, in uncased wells it is possible to perform hydraulic fracturing without slot initiators.

Chinakal Institute of Mining SB RAS has carried out a number of works [1–6] showing the operability of the approach in creating a crack across the borehole due to additional tangential loading of its walls. Figure 1 shows the schemes of hydraulic fracturing with tangential loading of the well walls, with an anchorage without an indenter.

The fluid pressure (P) pushes the device out of the well with a force equal to $\pi R^2 P$. This force is transferred to the anchor. The force generates tangential loading on the anchor’s contact with the well, which, together with the fluid pressure on the face, makes the model’s material stretch along the well axis. In the variant with an indenter this loading ($S_i$) is concentrated along the exit line formed by the indenter of the edge crack and its value is reaching $PR/2$. 

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A device for directional fracturing was developed based on the performed works. The device is a combination of a mechanical anchor (anchor) and pressure sealer (packer). A general view of the downhole equipment is shown in Figure 2.

The anchor element is made of a split disc spring 2 with a pointed outer edge. Unlike the more common wedge anchors, the system is small along the borehole axis, which makes it possible to reduce the length of the fracture interval to half the diameter of the borehole. The small contact area of the anchor with the rock provides high local tangential loading of the well walls along its axis. All the conditions reduce the probability of longitudinal fracturing and contribute to the formation of a transverse crack. Sealing devices 3 and 4 are made in the form of a section mounted into each other, which, due to the different rigidity of the used rubber, firmly covers the gap interval without the possibility of displacing the device relatively to the borehole axis.

Figure 1. Scheme of the loading on the borehole surface during hydraulic fracturing: (a) with tangential loading on the borehole walls; (b) anchorage without indentor.

Figure 2. General view of a downhole device used for setting screens at a depth of up to 200 cm from the side of the mine: 1 – detent; 2 – anchor; 3 – rigid rubber; 4 – soft rubber; 5 – packer’s pipe; 6 – packer’s nut; 7 – anchor’s pipe; 8 – anchor’s nut; 9 – heavy-duty pipe; 10 – inlet manifold
A heavy-duty pipe 9, a nut 8, a pipe 7, a split disc spring 2 and a detent 1 form the anchor part of the device. The spring 2 is made of 4–5 mm thick steel. The outer diameter of the spring in the transport position is 44–46 mm. The anchor is actuated by tightening the nut 8 on the thread of the pipe 9. This reduces the distance between the detent 1 mounted on the pipe and the end flange of the pipe 7. As a result, the spring 2 is compressed; its outer edge is pressed into the walls of the well.

A nut 6, a pipe 5 and sealing elements of different stiffness 3, 4 form the packer part of the tool. The external sealers 3 are made of rigid rubber with a conical ward at one of the ends. The inner sealer 4 is made of soft rubber with conical protrusions at both ends. The packer is actuated by tightening the nut 6 on the external thread of the pipe 7. As a result, the sealers 3 and 4 are compressed at the axis, increasing in diameter and overlapping the annular clearance between the pipe 5 and the well walls.

After installation of the tool a hydraulic collector 10 is screwed into the pipe 9. High-pressure hoses are connected to the hydraulic manifold to supply two-component working fluids. The working fluid enters the bottomhole fracturing interval through the annular clearance between pipes 9 and 7. The pressure of the working fluid generates additional compression of the anchor spring 2, as well as the tangential loading at the contact of the anchor element with the rock.

After the hydraulic fracturing the pipe 9 is unscrewed (left thread) from the detent 1 and extracted from the borehole. The remaining part of the device is used for long-term sealing of the fracture interval, measurement of pressure in the screen and pumping in it a filler to compensate for leaks. For this purpose, a special adapter is installed in the mouth of pipe 7. Upon completion of the work, the device is dismantled from the well, in which a non-retractable detent 1 and a disk spring 2 remain.

Conclusion
The developed construction will make it possible to create a transverse fracture of uncased wells without carrying out an additional creation of an initial crack by a slitter. The experimental verification of this method shows that when fracturing is performed with indenter a transverse crack was formed, which indicates the efficiency of the method of directional transverse fracturing.

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