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# Transverse Hydraulic Fracture Initiation by Indentation in an Uncased Borehole

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**Abstract**

The hydraulic fracturing technique has applications in the development of solid mineral deposits. The particularities of the method performed in a mine condition include confined space and high requirements for the safety of the equipment used in underground workings. One of the most relevant tasks in in-mine hydraulic fracturing is creating parallel cracks oriented across the axis of the well. In-seam boreholes with this type of fracture system can be used for coal bed methane production, sealing of degassing boreholes, controlled collapse of the roof and other applications. In this paper we consider transverse crack formation on borehole wall in a given plane when the fracture initiation occurs due to an indenter impression located between two inflatable packers. During indentation fracturing, fluid under high pressure is supplied and this contributes to crack propagation in the desired direction. On the basis of the calculation of the stress intensity factor for the semi-infinite plane with the edge crack affected by the forces applied at points on the plane surface the length of the formed crack is obtained. The results show that the force acting on the wall of the borehole with a 76–105 mm diameter will be sufficient to create an initiation fracture in a predetermined direction. To implement this approach an experimental device is developed. It is implemented as an additional module of the hydraulic fracturing tool and equipped with a system of three indenters. The design of the device allows to obtain a total acting force in one plane and this will increase the effectiveness of the impact.



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## 1. Introduction

Hydraulic fracturing is a widely used method in oil and gas production to increase hydrocarbon inflow to the wellbore. Under the influence of the high fluid pressure delivered into an isolated interval of the well, an artificial crack forms in the reservoir rock.

Subsequently, this method has been adopted in the mining of solid minerals. The in-mine hydraulic fracturing, for which the method is implemented, in wells drilled in underground conditions possesses distinctive limitations, such as limited space and strict safety requirements for the operated equipment. Usually hydraulic fracturing solves the following problems:

- Rock mass breaking for effective mineral extraction or for controllable roof collapse in underground openings
- Rock mass drainage to extract coal bed methane, drain, moisten, intensify in-situ leaching and saturate loose rocks with the cementing compounds
- Prevention and protection from water and gas showings
- Stress-state measurement of the rock mass

The hydraulic fracturing implementation depends on the information about the crack's appearance and opening process. This information provides the opportunity to predict the fracture's shape and location and to optimise its parameters. Depending on the mine depth, vertical stress may be bigger or smaller than horizontal components of the compression field. This leads to the crack tending to turn and spread along the maximum pressure when the fracturing is being performed, even if initially the crack has another direction.

In the case of in-mine fracturing, one of the most important tasks is to create several parallel cracks located across the well axis. Extended inseam wells with transverse crack systems can be used to intensify the coal bed methane production [1], to seal the degassing wells [2] and to weaken hard roof [3, 4], etc.

Analysis of the employed technical solutions of the transverse hydraulic fracturing shows that following methods can be used to form the initiating cracks:

a) Cutting of the initiating disk crack on the well's walls with the help of special equipment;

b) Indentation of the well's walls using hard-alloy tools.

It is a technically complicated and time-consuming task to form an initiating crack by the mechanical cutting of rock. As a rule, this kind of crack is formed with the help of slot cutting equipment [5, 6]. However, in the case of extended inseam boreholes, with lengths reaching 1000 m, this method is difficult to apply.

## 2. Simplified mathematical model and results

Let us consider the method of the transverse crack formation in which the crack is opened in a given plane on the well's axis due to the impression of an indenter located in a straddle packer assembly between two packers.

To optimise technical parameters for transverse fracturing initiation we consider the model below (see Fig 1). Let us assume that a wedge-shaped indenter is being pressed into the well's wall with the power $F_i$, thus, opening the edges of the existing crack with depth $a$. The force with which the indenter effects the crack edges is calculated by the formula $F_s = F_i / 2\,\mathrm{tg}\,\alpha$, where $\alpha$ is the wedge-shaped indenter angle. The stress intensity factor for the semi-infinite plane with the edge crack affected by the forces $F_s$ applied at points on the plane surface [7] is:

$$K_I = 0{,}8256\frac{F_s}{l}\sqrt{\frac{\pi}{a}}, \tag{1}$$

where $l$ is the length of the wedge-shaped indenter's cutting edge.