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Methane Drainage Borehole Drilling Technology Status of Ukraine

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Abstract

Basic methods of coal bed methane drainages through boreholes drilled from the surface and from underground were introduced. Drilling equipments, the borehole structure and the mechanism of hydrodynamic head affecting coal seams which contain methane were studied.

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As is well known, there are large quantity of methane and its homologous materials in coal beds. Methane is one kind of non-traditional clean energies which are cheap, convenient to exploit, environment friendly and clean. The United States of American, Poland, France and other coal countries all concern about the issue of exploiting methane resource from coal beds. Currently, Ukraine exploits methane by drainage hole drilling just in order to guarantee coal mine safety. Donbass coal seams are full of pores and saturated gas. The CBM (Coal Bed Methane) reserve is 25 trillion cubic meters. The average content of methane in coal is 8~25m³/T. The maximum of methane is 100~150m³/T in mined coal beds. The high gas saturation in coal beds causes series of problems related to production safety and ecology. These problems include coal-dust explosion, gas explosion and fires etc. Methane extraction in advance of mining in coal beds can reduce the danger of potential gas outburst. It can not only resolve the ecological issues but also obviously increase clean energy reserves.

There are two main methods to extract methane from coal and rocks—surface drilling and tunnel drilling. About the surface drilling, the drilling result will be affected by some limitations if the drilling across through coal beds and rock stratums at the same time. The quantity of gas will be
limited because the contact area between drilling holes and strata which these drilling holes across is small. For the tunnel drilling, there can be a series of drilling holes along the coal bed within the scope of tunnels. This can increase the contact area between drilling holes and coal beds and drilling holes don't contact with surrounding rocks. So, the gas in coal beds is extracted. Only some parts of gas from surrounding rocks will be extracted, these parts of gas will be filtered by coal beds.

The domestic drilling rigs (ZIF-650, ZIF-1200MP, LBS, UBC-1M etc.) and foreign drilling rigs (Atlas Copco Craelius, Terramec Company etc.) are adopted to our drilling construction.

The borehole diameter is more than 150 mm in the surface of drilling and the orifice tube should be fixed. The casing should be fixed in the borehole segment of gas saturation and surrounding rock. The borehole bottom should be deeper than the lower coal seam, and certain borehole segment should be reserved for containing cuttings and coal cinders. As shown in Fig. 1(a), hydrodynamic head control device is installed in orifice.

As is shown in Fig. 1(b) and Fig. 2, a group of boreholes arranged with a distance of 50m drill across rock pillars into coal seams. The borehole diameter is 150mm and the length is between 100m and 200m. The rock borehole segments are sealed. The hydrodynamic head control device can make the borehole gas pressure equals to the formation pressure. The reasonable pressure parameters should be chosen to ensure the realization of closure of the borehole bottom, and make sure gas can’t enter the tunnel during pressure unloading. In order to increase the effective influence radius of drilling and improve the gas quantity, a group of drainage holes should be constructed between
technological boreholes. This arrangement can control the influence of the hydrodynamic head to the gas drainage process more effectively.

Fig. 2. equipment arrangement

1-drift; 2-working space; 3-borehole in coal seam; 4-borehole in rock mass; 5-casing; 6-joint; 7 hydrodynamic head control device; 8-high pressure pipe; 9-compressed air branch pipe; 10-methane drainage manifold; 11-operating console; 12-compressed air manifold; 13-pump; 14-Fire water system; 15-methane sensor; 16-geotector; 17-telephone;

According to hydrodynamic damage principle, fluid seepage characteristics in porous gas saturation medium can be acquired. Whether fluid can fill out porous media or not depends on its physical and chemical junction condition, i.e., capillarity and adsorption phenomena. Capillary force can delay the flow in porous media to keep the water holding ability and affect flow resistance. According to Darcy law, seepage velocity can be determined by the following equation.

$$ v = \frac{k \frac{\partial P}{\partial r}}{\mu \frac{\partial r}{\partial t}} $$

(1)
In the formula, $k$-hydraulic conductivity, m$^2$; $\mu$-liquid viscosity, Pa·s; $\frac{\partial P}{\partial r}$ —pressure gradient, Pa/m.

Hydraulic coefficient of porous medium, different from its transmission coefficient, has nothing to do with the property of fluid. Both the nature and function parameters of porous media and the fluid determine the flow velocity of fluid in porous media. The purpose of exerting hydrodynamic head on porous medium is to set up pressure gradient on the free surface of porous medium by pumping water into stratums and unloading pressure. Therefore, the time for unloading pressure should be the short time which is needed for reversely exudating liquid.

Given:

$$\frac{\partial P}{\partial r} \approx \frac{P_n - P_c}{a}$$  \hspace{1cm} (2)

Fluid velocity equation is:

$$v = \frac{k}{a\mu}(P_n - P_c)$$  \hspace{1cm} (3)

And equation of time for reversely exudating is:

$$t_s = \frac{\mu a^2}{k(P_n - P_c)}$$  \hspace{1cm} (4)

In which, $P_n$-stratum pressure on gas, Pa; $P_c$-unloading pressure of fluid, Pa; $a$-seepage depth.

In term of the coal seam whose hydraulic conductivity equals $10^{-14}$m$^2$, when using the water, whose viscosity is $10^{-3}$Pa·s, as operating fluid, under the condition of pumping pressure 7Mpa and unloading pressure 1Mpa, we can get a result that the calculated value of seepage time equals 7s. In this case, seepage velocity equals $3 \cdot 10^{-3}$m/s.

Viscous friction, existing on the surface of fluid and pores, has resistance on fluid movement.

$$F_v = \frac{\mu a}{k}\frac{\Delta P}{\chi}$$  \hspace{1cm} (5)

Considering the volume of the pores which are full of fluid, the fluid seepage velocity is as follows:

$$F_v = \frac{\Delta P S}{\chi}$$  \hspace{1cm} (6)

In which, $\Delta P$-the difference of pumping pressure and unloading pressure, Pa; $S$-area of research region, m$^2$.

In this case, gas acts on the coal seam frame, which is full of fluid with $F_v$, to separate porous medium from rock mass. But intermolecular cohesion of coal seam prevents this separating process. The force needed to overcome the fracture strength breakpoint equals:

$$F_\sigma = \frac{S\sigma_p}{\chi}$$  \hspace{1cm} (7)
In which, $\sigma_p$-porous medium fracture strength breakpoint, Pa.
Porosity stratum medium will separate from rock mass under the following condition,

$$F_v > F_\sigma$$

i.e.

$$\frac{\Delta PSm}{\chi} > \frac{S\sigma_p}{\chi}$$

(9)

So the condition for separating porous medium is:

$$\Delta P = \frac{\sigma_p}{m}$$

(10)

In order to fracture the coal seam with the porosity $m=0.05$ and the ultimate fracture strength $\sigma_p=0.1$ Mpa, the difference between the pumping pressure and the unloading pressure should not less than 2 Mpa.

Except the strength criterion, to fracture also need to fit energy criterion. To form new surfaces the work done by viscous friction force $A_v$ must be greater than the essential energy $A_S$ for formulating these surfaces.

$$A_v > A_S$$

(11)

The work done by viscous friction force during unloading time is:

$$A_v = F_v \cdot v \cdot t c$$

(12)

In this formula, $t c$ stands for the unloading pressure time of porous medium surface.

Substitute the $F_v$ in the formula 6 and the $v$ in formula 3 to the formula 12, the work done by viscous friction force is:

$$A_v = \frac{\Delta P^2 S m k t_c}{\mu \chi a}$$

(13)

Surface energy is:

$$A_S = 2 S g s$$

(14)

In this formula, $g s$ stands for available surface energy, for coal $g s=10$ Pa·m².

Corresponding to the formula 11, the energy fracture criterion is:

$$\Delta P > \sqrt{\frac{2 g s \chi \mu a}{k m t_c}}$$

(15)

From this formula, relationships of the difference of pumping and unloading pressures with the coal seam property and unloading time can be defined.

Some original parameters should be known to determine the influence of the hydrodynamic head to the pressure gas saturation medium. These parameters include liquid pumping pressure and
unloading pressure in borehole (working), unloading time, loading-unloading cycle times, permeability of strata, viscosity of working liquid and fracture depth of coal seam.

Conclusion

The hydrodynamic head working on coal and rock mass can unload pressure effectively to release gas in the coal seam in a relative large area around the borehole.

A series of mathematic formulas can be used to calculate the difference between pumping and unloading pressures to fracture coal seam by the coal seam property and unloading pressure time.