UNDERGROUND MINING ENGINEERING 22 (2013) 1-5 UDK 62
FACULTY OF MINING AND GEOLOGY, BELGRADE YU ISSN 03542904

Original scientific paper

METHANE EMANATION FROM COAL SEAM SIDE FACE BY THE HIGH ADVANCE RATE OF DEVELOPMENT FACE

IZDVAJANJE METANA IZ UGLJENOG SLOJA PRI UBRZANOM NAPREDOVANJU TOKOM RAZRADE ŠIROKOG ČELA

Kachurin M. Nikolai[1], Kaledina O. Nina[2], Kachurin N. Alexander[2]

Abstract: It’s noted that the modern tendency of using "mine – longwall" technology will produce to increasing productivity of long-wall at 10 - 15 times and advance rate of development face will increase at several times accordingly. The results of theoretical analysis and foundation on basic regularity for forecasting methane emanation from coal seam side face were represented in this paper. It’s proved that methane emanation from coal seam side face by the high development face velocity is proportional to the product of the exponent with a negative argument multiplied by zero-order modified Bessel function with a positive argument. The physical model of the process was based and mathematical description for forecasting methane emanation from coal seam side face by the high advance rate of development face was shown and results of calculation experiments were shown too.

Key words: development working, methane, filtration, coal seam, gas emanation, physical model, mathematical model, forecasting

Apstrakt: Primećeno je da je prilikom primene tehnologije „širokog čela“ dolazi do povećenja produktivnosti i napredovanja prilikom formiranja otkopa od 10 do 15 puta. U ovom radu su prikazani rezultati dobijeni na osnovu teoretskih analiza i primene osnovnih postavki za predviđanje izdvajanja metana iz ugljenog sloja. Dokazano je da se izdvajanje metana iz ugljenog sloja prilikom velike brzine napredovanja tokom formiranja otkopa proporcionalno proizvodu negativnog eksponenta pomnoženog Beselovom funkcijom koja je modifikovana nultim redom sa pozitivnim koeficijentom. Fizički model procesa je zasnovan na matematičkom opisu predviđanja izdvajanja metana iz ugljenog sloja na čelu radilišta prilikom ubrzanog napredovanja tokom formiranja širokog čela. Ovo je prikazano u radu, kao i proračun koji je urađen na osnovu rezultata eksperimenta.

Ključne reči: radovi na razradi, metan, filtracija, ugljeni sloj, izdvajanje gasa, fizički model, matematički model, prognoza

[1] Tula State University, prosp. Lenina 92, 300600 Tula, Russia
[2] Moscow State Mining University, Lenin Avenue 6, 119991 Moscow, Russia

1. INTRODUCTION

Modern technologies and techniques of coal extraction ensure increasing mining faces productivity more than ten times as much. Demonstrably, it stipulates that velocity of development working face advance increasing at several times. That is way existing theoretical methane emanation from coal seam side face must be specified. Methane filtration process can be considered as laminar and one-dimensional, if we study coal extraction by the "Mine – Face" technology (Качурин et al. 2005).

2. MATHEMATICAL DESCRIPTION FOR FORECASTING METHANE EMANATION

The design diagram of methane emanation from coal seam side face into the development working for such conditions is shown in Figure 1.

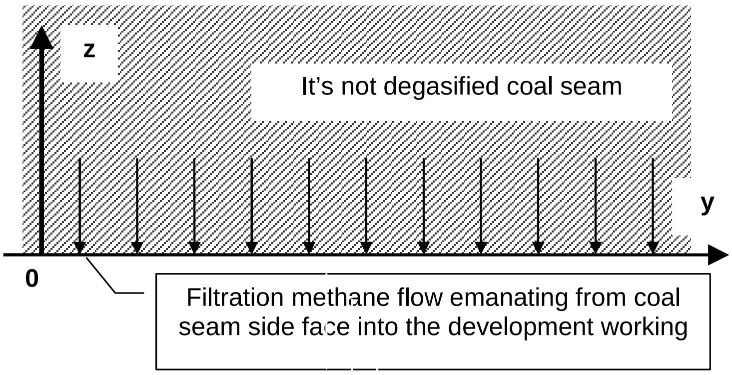

Figure 1 - The design diagram of methane emanation from coal seam side face into the development working

It is necessary to use filtration equation of the hyperbolic type, if the velocity of development working face advance is very much (Качурин, 1991). Therefore, mathematical description of free methane pressure field in boundary part of coal seam has follow form:

$$\frac{\partial p^2}{\partial t} + t_r \frac{\partial^2 p^2}{\partial t^2} = \chi_{c.s} \frac{\partial^2 p^2}{\partial z^2} \qquad (1)$$

where:

p - free methane pressure in cracks and pores of coal seam;

z - spatial value;

t - time;

t_r - relaxation period of laminar methane filtration process in coal seam;

$\chi_{c.s}$ - piezoconductivity of coal seam depending from filtration and sorption coal property.

Project length of the development working is more than seam thickness and sizes of natural gas drainage zone in ten or hundred times. Consequently, we can consider one-dimensional semi-infinite space and write initial conditions at follow form:

$$\left.\begin{aligned} &p(z,0)=p_o=const, \quad \frac{\partial}{\partial t}p(z,0)=0 \\ &p(0,t)=p_c=const, \quad \lim_{z\to\infty} p\neq\infty \end{aligned}\right\} \tag{2}$$

where p_o and p_c are free methane pressure in coal seam and in contact of development working atmosphere with coal seam side face, accordingly.

Solution of equation (1) for conditions (2) is following (Лыков, 1978):

$$\begin{aligned} \frac{p^2-p_o^{\,2}}{p_c^{\,2}-p_o^{\,2}} &= \Big\{\exp\left[-0.5z\left(t_r\chi_{c.s}\right)^{-0.5}\right]+0.5z\left(t_r\chi_{c.s}\right)^{-0.5}\times \\ &\times\int\limits_{z\left(t_r\chi_{c.s}^{-1}\right)^{0.5}}^{t}\left(\tau^2-z^2t_r\chi_{c.s}^{-1}\right)^{-0.5}\exp\left(-0.5\tau t_r^{-1}\right)\times \\ &\times I_l\left[0.5t_r^{-1}\left(\tau^2-z^2t_r\chi_{c.s}^{-1}\right)^{0.5}\right]\partial\tau\Big\}\sigma_o\left[t-z\left(t_r\chi_{c.s}^{-1}\right)^{0.5}\right] \end{aligned} \tag{3}$$

where:

$$\sigma_o\left[t-z\left(t_r\chi_{c.s}^{-1}\right)^{0.5}\right]=\begin{cases} 0 \; by \; t<z\left(t_r\chi_{c.s}^{-1}\right)^{0.5} \\ 1 \; by \; t\geq z\left(t_r\chi_{c.s}^{-1}\right)^{0.5} \end{cases}$$

Mass velocity of methane filtration is defined from the equation of gas mass balance (Лыков, 1978):

$$\rho v=\frac{\rho_a}{2p_a}\sqrt{\frac{\langle k\rangle m\alpha_p}{\mu t_r}}\exp\left(-\frac{0.5t}{t_r}\right)I_o\left(\frac{0.5}{t_r}\sqrt{t^2-\frac{z^2t_r}{\chi_{c.s}}}\right) \tag{4}$$

where are:

ρ_a - density of methane by atmospheric pressure p_a;

μ - dynamic viscosity of methane;

$\langle k\rangle$ m - average value of gas permeability and porosity of coal respectively;

α_p - parameter of linearization, which defining by follow formula:

$\alpha_p=(p_c-p_o)\ln p_cp_o^{-1}$

Analytical dependence for calculating specific methane emanation from coal seam side face $I_{s.s}$ follows from formula (5):

$$I_{s.s}=I_{s.i}\exp\left(-\frac{0.5t}{t_r}\right)I_o\left(\frac{0.5t}{t_r}\right) \tag{5}$$

where $I_{s.i}$ is initial velocity of methane emanation, ($m^3/m^2 \cdot$ minute).

Asymptotic expansion of modified Bessel function for large value of the argument has the appearance:

$$I_o\left(\frac{0.5t}{t_r}\right) \approx \exp\left(\frac{0.5t}{t_r}\right)\sqrt{\frac{t_r}{\pi t}}$$

That is way the formula (5) has the follow appearance for large time periods, which exceeding construction duration of a development working:

$$I_{s.s} = 0.5641 I_{s.i}\sqrt{\frac{t_r}{t}} \tag{6}$$

The methane emanation into the development working $I_{s.w}$ from elementary coal seam side face *dS,* with using formula (5), can be defined at follow appearance:

$$dI_{s.w} = nI_{s.s}dS = m_{c.s}V_{w.f}I_{s.i}\exp\left(-\frac{0.5t}{t_r}\right)I_o\left(\frac{0.5t}{t_r}\right)dt$$

where are:
n - is quantity of coal seam side faces, which contacting with development working air;
$m_{c.s}$ - coal seam thickness;
$V_{w.f}$ - advance rate of development working face.

Consequently, the methane emanation into the development working from elementary coal seam side face with using integral form of modified Bessel function can be defined by follow formula:

$$\begin{cases} I_{s.w} = 0.318 nm_{c.s}t_rV_{w.f}I_{s.s}\int\limits_0^{t/2t_r}\exp(-\tau)\times \\ \times\left\{\int\limits_0^{\pi}\left[\exp(\tau\cos\theta) + \exp(-\tau\cos\theta)\right]d\theta\right\}d\tau \; by \; t \le T_{DW}, \\ 0.564 nm_{c.s}L_{DW}I_{s.s}\sqrt{\frac{t_r}{T_{DW}+t}} \; by \; t < T_{DW} \end{cases} \tag{7}$$

where are:
L_{DW} - project length of the development working;
T_{DW} - construction duration of the development working.

The formula (7) is correct for all construction duration of the development working. The upper limit of the external integral is non-dimensional time, which past from beginning construction duration of the development working $\tau_{d.w}$.

Let us introduce follow limitation:

$$\overline{I_{s.w}}(\tau_{d.w}) = \pi I_{s.w}\left(nm_{c.s}t_rV_{w.f}I_{s.s}\right)^{-1} \quad by \quad t \le T_{DW}$$

$$\overline{I^*_{s.w}}(\tau_{d.w}) = 1.254 I_{s.w}\left(nm_{c.s}L_{DW}I_{s.s}\right)^{-1} \quad by \quad t > T_{DW}$$

$$\tau_{d.w} = t/2t_r; \quad \Theta_{DW} = T_{DW}/2t_r$$

where are:
$\overline{I_{s.w}}(\tau_{d.w})$ - non-dimensional methane emanation into development working from coal seam side face at construction working period;

$\overline{I^*_{s.w}}(\tau_{d.w})$ - non-dimensional methane emanation into development working from coal seam side face at detached ventilation period for the working with length is equal to L_{DW}.

A calculation experiment was realized with using formula (7). Results of the calculation experiment show that we can use follow formulas for engineering calculations:

by $\tau_{d.w} \le \Theta_{DW}$

$$\overline{I_{s.w}}(\tau_{d.w}) = \begin{cases} 3.73\tau_{d.w}^{0.68} & at \quad 0 \le \tau_{d.w} < 3 \\ 4.571 + 1.143\tau_{d.w} & at \quad 3 \le \tau_{d.w} < 10 \\ 10 + 0.5\tau_{d.w} & at \quad 10 \le \tau_{d.w} < 50 \\ 25 + 0.26\tau_{d.w} & at \quad 50 \le \tau_{d.w} < 100 \end{cases} \tag{8}$$

by $\tau_{d.w} > \Theta_{DW}$

$$\overline{I^*_{n.b}}(\tau_{d.w}) = (\Theta_{DW} + \tau_{d.w})^{-0.5} \tag{9}$$

Approximations of given by formula (8) have values of correlation coefficient 0.92 … 0.94. Approximation fractional error is less than 3%. Formulas (8) and (9) show that methane emanation intensity is connected with advance rate of development working face and project length of the one. Analyzing these dependences shows that methane emanation is increasing during construction development working process at the expense of increasing surface area of coal seam side face. The surface area of coal seam side face has differential of square pressure is equal to $p_o^2 - p_c^2$.

3. CONCLUSION

Degassing coal seam part contacting with development working air is obtained by hyperbolic law. Revealed theoretical dependences make it possible first of all to increase of forecasting reliability of methane emission into development workings by the high advance rate of development face and secondly to evaluate of forecasting efficiency of degassing systems.

REFERENCES

[1] КАЧУРИН, Н.М. (1991) Перенос газа в породоугольном массиве. *Известия вузов, Горный журнал,* 1, pp. 43–47.

[2] КАЧУРИН, Н.М. et al. (2005) *Аэрогазодинамика углекислотообильных шахт*. Москва: МГГУ.

[3] ЛЫКОВ, А.В. (1978) *Тепло-массообмен*. Справочник - Энергия.