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Abstract

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ON THE MOTION OF AIR THROUGH MINE WORKINGS IN THE PRESENCE OF GOAFS

(Presented by Academician A. A. Skochinsky, 9 XI 1956)

Goafs in a mine have a substantial effect on the aerodynamics of the mine ventilation system. This is due to the fact that the ventilation jet, flowing around mine workings, over an interval of 200–300 m near working coal faces loses part of the air (sometimes a very considerable amount) as a result of its branching into the goaf, whether collapsed or stowed.

The present paper sets out a method by means of which one can give a general qualitative assessment of the motion of air through mine workings adjoining a goaf, and calculate the magnitude of air leakage through this space. The need for such analysis and calculation arises in designing mine ventilation.

1. The motion of air through a mine working (a drift) bordering on a goaf is described by the equation (see, for example, (4))

$$\frac{r(x)l}{m^n}\left(\frac{dQ}{dx}\right)^n = R\int_0^x Q^2(x)\,dx + Q_0^2 R_2 l, \tag{1}$$

where $Q(x)$ is the quantity of air flowing through the cross section of the haulage drift located at a distance x from the longwall face (Fig. 1); Q_0 is the quantity of air reaching the longwall face; $R = R_1 + R_3$ is the total specific aerodynamic resistance of the haulage (R_1) and ventilation (R_3) drifts; R_2 is the specific aerodynamic resistance of the longwall face; $r(x)$ is the specific aerodynamic resistance of the goaf; n is the exponent in the resistance law for the motion of air in the goaf ($1 \leq n \leq 2$); l is the length of the longwall face; m is the thickness of the seam being mined.

Equation (1) cannot be integrated in general form. The introduction into (1) of certain assumptions and simplifications (2,3) removes the mathematical difficulties to some extent, but introduces distortions into the physical formulation of the problem and cannot yield a qualitatively correct approximate solution.

Fig. 1

Figure 1: Fig. 1

Moreover, the solutions proposed earlier ($^{1-4}$) do not possess sufficient generality, since they were obtained for special cases of the exponent n and the function $r(x)$.

Using the fact that the variable x varies over a bounded interval (approximately $0 < x < 300$ m), one can obtain an approximate solution of equation (1) by a method in which, instead of continuously distributed air leakages, a concentrated ("fictitious") flow is considered, branching off from the ventilation jet at one specially chosen point. In contrast to works ($^{1-4}$), the proposed method does not impose any restrictions on the exponent n or the function $r(x)$.

2. To replace a continuously distributed leakage flow by a concentrated one, the concept is introduced of the total aerodynamic resistance R_x of the goaf to the motion of air in the direction of the leakages (i.e., from the haulage to the ventilation drift). Considering the leakage flow as a set of a large number of parallel jets, we find that the indicated resistance is equal to

$$R_x = \frac{l}{\left[m \int_0^x \frac{dx}{\sqrt[n]{r(x)}}\right]^n}. \tag{2}$$

If, over the length x of the mine working, q_x m^3/sec of air is lost, then the relation holds

$$h_x^* = R_x q_x^n$$

or

$$h_x^* = R_x [Q(x) - Q_0]^n, \tag{3}$$

where h_x^* is a certain mean (reduced) air-pressure drop between the haulage and ventilation drifts.

Fig. 1

In the case of a parallel connection of several jets, the pressure difference between nodal points is equal to the pressure difference along the path of any of the jets entering the given connection. In the diagram of Fig. 1, the parallel leakage jets branching off from the flow following the working AB are not connected at a single point, but issue onto the straight line CD (the ventilation drift). Therefore, owing to the continuity of the variation of the pressure drop, the value h_x^* lies within the limits

Fig. 2

Figure 2: Fig. 2

$$h_{BC} < h_x^* < h_{AD}$$

or

$$R_2 l Q_0^2 < h_x^* < R_2 l Q_0^2 + R \int_0^x Q^2(x)\, dx. \tag{4}$$

Fig. 2

On the basis of inequality (4), h_x^* may be represented in the form

$$h_x^* = (R_2 l + R\beta x) Q_0^2, \tag{5}$$

where β $(0 < \beta < 1)$ is a certain function of x, determining the position of the point M at which the "fictitious" leakage flow branches off (Fig. 1).

From (3) and (5) it follows:

$$R_x [Q(x) - Q_0]^n = (R_2 l + R\beta x) Q_0^2. \tag{6}$$

Equation (6) is an approximate substitute for equation (1). To use (6) it is necessary to know the value of the parameter β. As the subsequent investigation shows, with accuracy sufficient for practice it may be assumed that the point at which the "fictitious" leakage flow branches off lies on the straight line MN (Fig. 1), which divides the goaf into parts with equal total resistances:

$$R_{MBCN} = R_{AMND} = 2^n R_{ABCD}.$$

Under this assumption, using (2), we determine β from the equation

$$2 \int_0^{\beta x} \frac{dx}{\sqrt{r}} - \frac{dx}{\sqrt{r}} \tag{7}$$

Substituting into (6) the expressions for R_x from (2) and for β from (7), we obtain the desired function $Q(x)$ in explicit form.

3. Figure 2 shows the solution of equation (1) for specific numerical data with $r(x) = \text{const}$ and $n = 1$, obtained by the isocline method (curve 1), and an approximate solution by the "fictitious" flow method (curve 2). In the interval $0 \le x \le 300$ m the discrepancy between curves 1 and 2 is insignificant.

Fig. 3

Figure 3: Fig. 3

Fig. 3

The dependence $r(x)$, determined on the basis of experiments in mines, can be represented in the form of an exponential function $r(x) = r_0 e^{\alpha x}$ (1). In this case, for a linear law of resistance to the motion of air in the mined-out space ($n = 1$), the "fictitious" flow method leads to the following expression for $Q(x)$:

$$Q(x) = Q_0 + \frac{Q_0^2 m}{l r_0 \alpha} \left(\frac{R}{\alpha} \ln \frac{2}{1 + e^{-\alpha x}} + R_2 l \right). \tag{8}$$

Figure 3 shows the graphs of $Q(x)$ for the conditions of one of the longwalls of the Katanovich Mine (Donbass): 1—the result of measurements in the mines (4); 2—according to one of the previously proposed formulas (4); 3—according to formula (8). As is evident from Fig. 3, the solution of equation (1) by the "fictitious" flow method has sufficient accuracy.

4. It should be noted that at present, when designing installations for studying mine ventilation networks by the method of electrohydrodynamic analogy (5, 6), the influence of mined-out spaces on mine aerodynamics is not taken into account. The introduction of the concept of a "fictitious" flow of air leakage through a mined-out space makes it possible to eliminate this inaccuracy of electrical modeling easily.

In conclusion, the author takes this opportunity to express deep gratitude to Academician A. A. Skochinsky for valuable guidance and attention to the work.

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Note: Figure translations are in progress. See original paper for figures.