



Full Length Research Paper

Optimum friction factor of Algerian Mines

K.M.Behim ;T.Serradj ; A.E. Hadjadj

University of Badji Mokhtar Annaba, Faculty of Earth Science, Mining Department
 Algeria
 Metallurgical Laboratory and Materials properties

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One of the most important parameter in mine ventilation planning is the friction factor (K). Accurate values of friction factors are critical especially when carrying out mine ventilation simulations. No computer simulation of a mine ventilation network is meaningful if the airway resistances are not accurately estimated or measured. The friction factor between the airflow and the lining in an excavation in a typical mine is the aim of this research . This paper describes the measurement techniques and results from friction factor measurements taken during ventilation surveys at various Algerian’s mines with different support systems. A comparison between experimental and numerical values is also presented.

Keywords: Friction factor, résistance, ventilation, simulation, Algerian’s mines

INTRODUCTION

In excavation works, with depth increase, the ventilation network becomes more complicated as far as the aerodynamic résistance is concerned. The airflow in the underground excavation would have to exceed the aerodynamic résistance. This résistance to air movement is designed by (R), which depends not only on the geometry parameters of the airway but also on the state of the surface of the lining (roughness) (Ian, 1997). (R) is expressed as:

$$R = k \left(\frac{L \times P}{S^3} \right) \quad (1)$$

Where, L, P, S: are, the length of the airway (m), airway perimeter (m) and the cross-sectional area (m²)

respectively; k is the Coefficient, which represents the loss of the energy, caused by air friction against the walls

This study is focused on the coefficient (k), which depends on the state of the wall surface of different lining . A modelisation is done in the laboratory, the results are compared to a calculated friction factors of three Algerian mines. A solution to the problem is suggested in order to minimise the friction coefficient (k).

The following cases are considered:

- Smooth ducts
- Rough ducts
- Mine airways

In these three cases, the study is focussed on the airflow regime that is characterised by the Reynolds's number:

$$R_e = \frac{V \times D}{\nu} \quad (2)$$

Where: ν : air velocity (m s⁻¹)

D : hydraulic mean diameter (m)

ν : coefficient of kinematic air viscosity (m² s⁻¹)

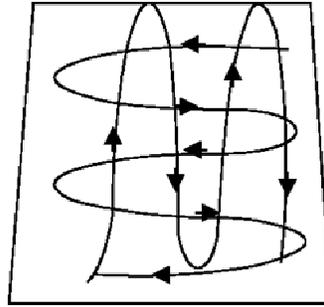


Figure 1. Sweepmethod

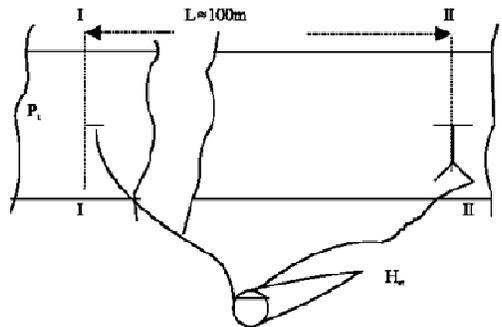


Figure 2. Schematic of the differential static pressure measurement

Airflow in the mine airways

The air cannot be considered as an incompressible fluid, it is still possible to apply the incompressible fluid equations, if the ducts of the flow are designed such as the air density varies slightly from one point to another of the airway.

The order of error committed by this assumption is in the range of 5 to 7 %, which can be considered to be an acceptable error. In order to merely account for the resistance due to the friction of the air against the airway walls, we assume that the airflow throughout a straight and horizontal airway, with constant area and without congestion. In this case we can apply Bernoulli's law (Ouchakov and Bourtachakov, 1971):

$$(p_1 - p_2) + (\gamma_1 Z_1 - \gamma_2 Z_2) + \left(\frac{\gamma_1 V_1^2 - \gamma_2 V_2^2}{2g} \right) = \Delta h \quad (3)$$

Where (Ah), represents the total energy of all external forces during the movement of a certain volume of air. For the real conditions in the mine we take: $V_1 = V_2$; $Z_1 = Z_2$ and $\gamma = \text{constant}$

In this case, Eq. (1) becomes:

$$P_1 - P_2 = \Delta h = \int_1^2 dh \quad (4)$$

Figure 1, may be expressed in terms of the force of friction (H_{fr}) per unit length (dx):

$$dh = H_{fr} \times dx \quad (5)$$

Since (dh) represents the work of the friction forces per unit length, then (H_{fr}) will become the friction force per unit volume. This may be expressed as:

$$H_{fr} = \frac{\tau \times p_1}{S_1} \quad (6)$$

Where: τ : shear stress

p_1 : cross sectional area of the lining per unit length

S_1 : volume of the airway by unité of length

The combination of Eq. 4, 5 and 6 gives:

$$p_1 - p_2 = \frac{p}{S} \int_1^2 \tau \cdot dx \quad (7)$$

From hydraulic concepts we also know that:

$$\tau = \beta \times \rho \left(\frac{v^2}{2} \right) \quad (8)$$

Where: β : friction coefficient (dimensionless),

ρ : air density and v, mean air velocity

$$\beta = \frac{E_{fric}}{E_{kins}} \quad (9)$$

Where: E_{fric} : friction energy

E_{kins} : kinetic energy

$$h = p_1 - p_2 = \frac{\beta \rho \times p \times L}{2 \times S} V^2 \quad (10)$$

Where :

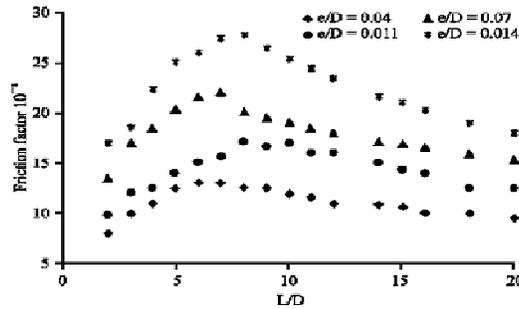


Figure 3. Expérimental results of the friction factor in fonction of the 1/D and the relative roughness (squared frame)

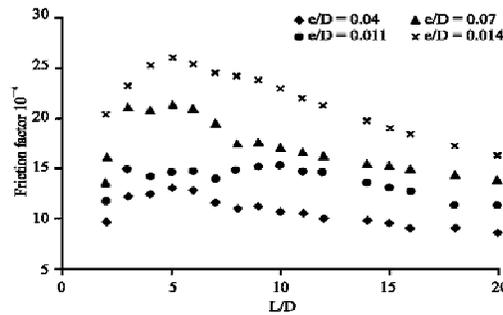


Figure 4. Expérimental results of the friction factor in fonction of the 1/D and the relative roughness (circular frame)

$$\rho = \frac{Y}{g} \quad (11)$$

and

$$V = \frac{Q}{S} \quad (12)$$

then

$$h = \frac{\beta \times Y}{2 \times g} \times \frac{P \times L}{S^2} Q^2 \quad (13)$$

$$k = \frac{\beta \times Y}{2 \times g} \quad \left(\frac{kg \cdot s^2}{m^4} \right) \quad (14)$$

k, is called the friction factor

$$h = k \times \frac{L \cdot P}{S^2} Q^2 \quad (15)$$

It can be seen from Eq. 15 that the value of (h) depends on the shape of the cross section. This latter gives the value of the perimeter (P), for a given constant section (S).

Measurement of in-situ aerodynamic parameters

In this study we describe the methods used to measure the atmospheric and ventilation parameters of three

Algerian mines namely *Ain mimoun*, *Kherzet youcef* and *El abed*. It is essential to présent the means and techniques used, where the accuracy of the results depends especially on the quality of the apparatus and the methods of measurements used.

The détermination of these parameters will allow us to calculate the numerical values of the aerodynamics résistance of each airway being considered and the following équation is used (Brian and Wallance, 1999):

$$k = \frac{H_{st} \times S}{L \times P \times V^2} \quad (16)$$

Where: H_{st} , is the differential static pressure (mm.c.w) S, L, P, are respectively the cross section (m^2), the length (m) and the perimeter (m) of the airway V, is air velocity ($m \cdot s^{-1}$)

Measurement of the airvelocity (Sweep method) Simode, 1962

This method consists of sweeping the airflow with the anemometer as shown in Fig. 1.

An operator will be standing in the middle of the airway

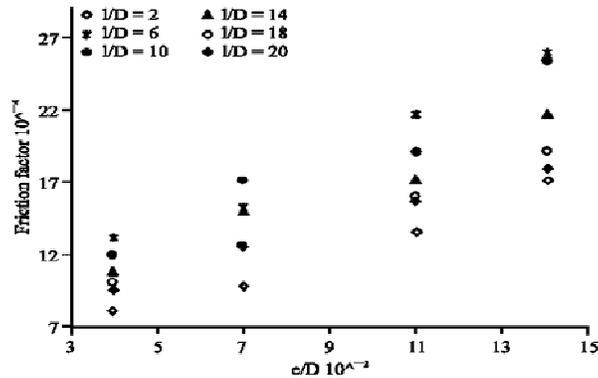


Figure 5. Nomogramme of détermination of friction factor in fonction of the relative roughness for squared frame

Table 1. Results comparison (mines versus simulation)

Mines	(l/d)	Δ_{mesure}	$k \cdot 10^{-4}$ (mine)	$k \cdot 10^{-4}$ (modèle)
El-Abed	18,6	0,023	6,40	8,10
	12,9	0,023	6,60	8,50
	6	0,067	13,52	14,60
AIN-MIMOUN	1	0,075	9,80	10,60
	1	0,075	9,60	

facing the airflow direction and handling the anemometer with the arms stretched forward describing a trajectory as shown in Fig. 1.

During the détermination of the air velocity, the initial indication of the apparatus has to be taken after that we turn on the anemometer by mean of fans in parallel we fixed the time at about an average of 100 s. We sweep the airflow in the direction as shown in Fig. 1. After each measure, we calculate the différence between the final and the initial records, we repeat this opération two to three times.

In the beginning of the measurement we have to take the record in three scales of the anemometer (thousands, hundreds and the units), after that we turn on the anemometer by mean of the fans, which unlock the meter and the chronometer in order to fix the time (t). After recording the time and the final indication on the anemometer, we calculate the number of divisions per second with the following équation:

$$N = \frac{N_{fin} - N_{int}}{t} \left(\frac{div}{s} \right) \quad (17)$$

Where :

N_{fin} is the final reading, N_{int} is the initial reading and t is the time of measurement

The value of (N) (div s⁻¹), allows us to find the air velocity using the conversion curves that come with the anemometer.

Pressure measurement Brian and Loomis, 2004

To measure the dépression between two parts of the airway, we must choose one site that fulfills the following conditions:

- Constant area over a distance of 60 to 120 m in average
- No congestion is allowed in the considered airway, such as (conveyor, automatic machine)
- A regular wall support

Based on Bernoulli's Eq. (3) and the conditions mentioned above we can assert that the static differential pressure solely détermine the energy loss.

This measurement is obtained by placing two pitot tubes distant 70 m apart. These are linked to a micro manometer using two flexible (5 mm diameter) pipes.

GEOMETRICAL PARAMETERS MEASUREMENT

In order to détermine the value of the coefficient (k), the geometrical characteristics of the airway such as its length, area and perimeter need to be measured. The coefficient (k) is given by :

$$k = \frac{H_{st} \times S^2}{P \times L \times Q^2} \quad (18)$$

The precision of calculating the above coefficient is

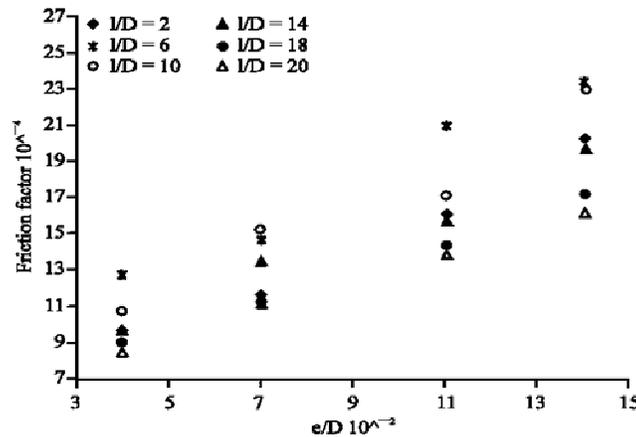


Figure 6. Nomogramme de détermination de friction factor in fonction of the relative roughness for circular frame

much dépendant on the précision in measuring the parameters (L), (P) and (S). Given that (S) is a cubic factor in the formula (18), its influence on the result is the most significant. Measuring the distance between the two pitot tubes is achieved by chaining using a double decameter. This method leads to a higher précision.

Measuring the airway's area and perimeter

The most accurate measurement is required for the section of the airway. This is due to the fact that the shape of the cross section in mine workings is usually irregular and causes measurement errors. For this reason an indirect measuring technique is used to reduce errors below 10%. The indirect method is realised by means of a dispositif called photoprofil. This apparatus allows us to shine the perimeter of the cross-section area of the airway. A picture is taken with a caméra after processing the film the border of the mine working appears shilling by mean of the photoprofil.

The result of the measurement and calculation are shown.

PHYSICAL PROTOTYPE

The study of the physical prototype is based on the knowledge and the calculation of the simulation criteria, which are:

- Géométrie similarity
- Kenitic similarity
- Dynamic similarity

The apparatus used during the simulation:

- Micro- manometer
- Psychometer
- Barometer

- Three pitot tubes and flexible pipe

Prototype description

Made on 1/20 scale, the airway has a trapezoidal shape, made of wood and supported by wooden frame of 5,10, and 15 mm, 20 mm for a squared frame and 20 mm diameter for a circular frame. The test was that we have to change only the distance between the support frame (1).

RESULTS AND DISCUSSIONS

The results of the laboratory work are presented in Fig. 3 and 4. It has been noticed from the expérimental work and the in-situ measurement that for the same shape of frame the results are nearly similar. Then, from the expérimental results the monogrammes are drawn to détermine the friction factor in fonction of the relative roughness of the airway and the value of (1/D). These monogrammes are presented in Fig. 5 and 6.

This study was related to the variations of the value of (k) representing the coefficient characterizing the roughness surface state and consequently its influence on aerodynamic braking of the air draught.

The value of (k) varies in broad measurement; that one can decrease up to 80%, by panels of garnishing out of plastic.

To decrease to a minimum value of (cc), will have a double aspect economie as well as hygienic, due to energy saving, accompanied to the respect of the established médical standards.

The ideal form of work is circular, since the ratio is minimal, which means that the coefficient form is equal to 1.

In this study we simulated the work area of 60 m length and a section equal to 12 m^2 , the model is on a scale of (1/20), a trapezoidal shape and supported by circular and squared frames of various diameters and various ratio (l/D).

The monograms were drawn by interpolation methods show clearly that:

(k) increases if (e/D) increases

(k) = maximum if $5 < (l/D) < 7$ for the squared frame

(k) = maximum if $4 < (l/D) < 6$ for the circular frame

where: (e/D) is the relative roughness and (l/D) is the longitudinal gauge.

CONCLUSION

It should be noticed, that it is necessary to determine by stability calculations of the work ratio (l/D) in order to compare it with the lowest corresponding value of (k).

These monograms help engineers to find the value of the friction factor during the ventilation networks project. The obtained results of the aerodynamic resistance value of the works supported by wood or metal, are comparable with the results obtained on the physical model. To notice that the aerodynamic parameters of the

Ain-mimoun mine, represent the best case of similarity in comparison with the laboratory model, this taking into account the form of the works, the diameter of the executives of supporting, the distance between them and the value of the cross-section of the galleries.

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