Friction factors determination and comparison in potash mines

Marc Bascompta Massanés (a)*, Lluís Sanmiquel Pera (a) Hernán Francisco Anticoi Sudzuki (b)

a Iberpotash Chair in Sustainable Mining, Polytechnic University of Catalonia, Manresa, Spain

b Department of Mining and Natural Resources, Polytechnic University of Catalonia, Manresa, Spain

* mbascomptem@gmail.com

ABSTRACT

Friction factor is a crucial parameter for assessing and modelling the ventilation system in underground mining. However, the development of a mine along its life can complicate the airflow supply required to the working faces, creating setbacks in terms of productivity and production. For this reason, it is very important to determine all the ventilation parameters. This paper examines data collected from different surveys carried out in two potash mines –both using a room and pillar exploitation method– with the idea of determining the friction factors through the Von Kármán equation, which connects the Atkinson friction factor with roughness of the airways. Standard values of such type of mining have been obtained, determining the roughness variation along the year due to surface climatic, which influences the shape and geometry of the tunnels in evaporitic exploitations.

KEY WORDS: Mine ventilation, friction factor, potash mining.

1.- INTRODUCTION

Flow of the air through airways will be determined by characteristics of the tunnels and obstacles placed in the ventilation circuit such as conveyors or other equipment. Among them, one of the most important aspects to take into account is the friction factor, which is conditioned by geometric characteristics of the tunnels, exploitation method and physic conditions of the mine [1], influencing the resistance of the tunnels to let the air flow [2]. These features define the airflow behaviour along the mine and its knowledge will be necessary for modelling the ventilation system [3]. Nevertheless, current information is mainly focused on coal and metal mines. McElroy published one of the first studies in this field based on pressure loss collected from several mines [4]. Subsequent studies extended the information considering the evolution of the sector [5-9].

This paper determines the friction factors of two underground potash mines using continuous mining machines in a room and pillar method. Intrinsic features of such exploitations, potash or salt, have special influence the ventilation system due to their plastic properties; deforming the tunnels along the time, due to pressure from surrounding rock, and causing constant variations in the roughness of the airways. In addition, temperature and humidity surface changes have also influence to the stability of the airways and therefore to the roughness rate.

2.- VENTILATION THEORY

Friction factor determined through roughness of the tunnels will produce a pressure drop, affecting the airflow. This value can be obtained using equation (1), which is a form of the Chezy–Darcy expression.

$$p = f\mathrm{L}\frac{\mathrm{Per}}{\mathrm{A}}\rho\frac{u^2}{2}\ \text{(Pa)} \qquad (1)$$

Where f is coefficient of friction (dimensionless); Per is airway perimeter (m); A is the area (m^2); ρ is air density (kg/m^3); u is air velocity (m/s) and L is length of the airway (m). Later on, equation (1) was adapted to the well-known Atkinson equation (2), expressed in frictional pressure drop.

$$p = \mathrm{kL}\frac{\mathrm{Per}}{\mathrm{A}}u^2\ \text{(Pa)} \qquad (2)$$

Where k is the friction factor (kg/m^3). The same equation can also be showed in terms of resistance using the square law, equation (3), and taking into account any other air density inside the mine due to pressure or temperature factors [10].

$$\mathrm{R} = \frac{\mathrm{p}}{\mathrm{Q}^2} = \mathrm{kL}\frac{\mathrm{Per}}{\mathrm{A}^3}\frac{\rho}{1.2}\ (\mathrm{Ns}^2/\mathrm{m}^8) \qquad (3)$$

The Atkinson friction factor is not a constant value, it varies depending on the Reynolds Number. However, flow of the air in the vast majority of underground places is turbulent in nature except in few cases such as behind the stoppings [11]. Von Kármán equation gives a relationship with the friction factor from Atkinson expression for turbulent flows. Equation (4) is applicable to circular and non-circular airways by means of the hydraulic mean diameter and calculated using the following relationship, Dh=4A/Per.

$$f = \frac{2k}{\rho} = \frac{1}{4 \cdot \left[2 \cdot \log_{10}\left(\frac{Dh}{e}\right) + 1.14\right]^2} \text{ (Dimentionless)}, \quad (4)$$

Where Dh is the hydraulic mean diameter of the tunnel (m); e is the height of the roughening (m).

3.- METHODOLOGY

Determining roughness and therefore friction factors from a ventilation system needs a database of the airways features [12]. Thus, several points from the ventilation circuit of both mines have been chosen to stand for the airways characteristics. Measures used in the paper have been collected between 2008 and 2014 and the following list details the parameters taken into account.

Point identification	Date
Section	Roughness
Shape of the airway	Dry and wet temperatures
Length	Air velocity

Mean values of section, shape, temperatures, length and air velocity have been used for obtaining the results, meanwhile roughness have been measured five times every time in each point using a tape measure and considering the most representative conditions of the zone. Afterwards, mean roughness values have been classified regarding the four seasons of the year. In order to facilitate the comprehension and processing of the data, mines are distinguished as Mine1 and Mine2 from here on.

4.- RESULTS

Outcomes from both mines are displayed by season and globally as well as their corresponding standard deviation. Apart from parameters included in the previous section, mean values of perimeter, hydraulic diameter and coefficient of friction from each control point have been determined in both cases. Tables 1 and 2 show the friction factors of each point in Mine1 and Mine2. Nomenclature used to identify the points is based on information provided by the company and their number varies depending on the different ventilation layouts and number of points required for representing the airway conditions of all circuit.

Table 1. Mean friction factors and standard deviation from each point in Mine1

Point	Spring k (kg/m^3)	Summer k (kg/m^3)	Autumn k (kg/m^3)	Winter k (kg/m^3)	Annual k (kg/m^3)	Standard deviation
0	0.01163	0.01134	0.01168	0.01184	0.01162	0.00021
1	0.00821	0.00801	0.00822	0.00838	0.00820	0.00015
2	0.00835	0.00848	0.00835	0.00853	0.00843	0.00009
3	0.00794	0.00778	0.00787	0.00802	0.00790	0.00010
4	0.00781	0.00796	0.00781	0.00796	0.00788	0.00009
5	0.00743	0.00701	0.00750	0.00739	0.00733	0.00022
6	0.00876	0.00872	0.00875	0.00933	0.00889	0.00029
7	0.00860	0.00856	0.00857	0.00856	0.00857	0.00002
8	0.00894	0.01014	0.00900	0.00940	0.00937	0.00055
9	0.00947	0.00787	0.00952	0.00900	0.00896	0.00077
10	0.00890	0.00890	0.00900	0.00893	0.00893	0.00005
11	0.00735	0.00729	0.00738	0.00732	0.00733	0.00004
12	0.00690	0.00686	0.00677	0.00677	0.00682	0.00007
13	0.00798	0.00855	0.00803	0.00821	0.00819	0.00026
14	0.00956	0.00956	0.00963	0.00956	0.00958	0.00003
15	0.00758	0.00694	0.00821	0.00759	0.00758	0.00052
A	0.01081	-	0.01207	0.01088	0.01125	0.00071
D	0.00956	-	0.00972	0.00960	0.00963	0.00009

Table 2. Mean friction factors and standard deviation from each point in Mine2

Point	Spring k (kg/m^3)	Summer k (kg/m^3)	Autumn k (kg/m^3)	Winter k (kg/m^3)	Annual k (kg/m^3)	Standard deviation
A	0,00655	0,00665	0,00664	0,00661	0,00661	0,00005
1	0,00709	0,00686	0,00720	0,00716	0,00708	0,00015
B	0,00614	0,00594	0,00623	0,00620	0,00613	0,00013
C	0,00589	0,00570	0,00598	0,00595	0,00588	0,00012

D	0,00546	0,00555	0,00554	0,00551	0,00551	0,00004
4	0,00601	0,00582	0,00610	0,00607	0,00600	0,00013
I	0,00594	0,00633	0,00603	0,00600	0,00607	0,00017
G	0,00549	0,00531	0,00557	0,00554	0,00548	0,00012
R	0,00697	0,00675	0,00708	0,00704	0,00696	0,00015
H	0,00680	0,00658	0,00690	0,00687	0,00679	0,00014
11	0,00758	0,00733	0,00769	0,00765	0,00756	0,00016
12	0,00794	0,00699	0,00733	0,00729	0,00739	0,00040
V	0,00745	0,00721	0,00756	0,00752	0,00743	0,00016
K	0,00833	0,00806	0,00845	0,00841	0,00831	0,00018
L	0,00632	0,00611	0,00641	0,00638	0,00631	0,00013
M	0,00832	0,00805	0,00844	0,00840	0,00830	0,00018
N	0,00769	0,00744	0,00776	0,00776	0,00766	0,00015
9	0,00862	0,00834	0,00874	0,00870	0,00860	0,00018
8	0,00978	0,00946	0,00992	0,00987	0,00976	0,00021

Once friction factors are determined a comparison between both mines can give insight of the margin variation and concordance among them. Table 3 compares the mean friction factors of all the points regarding each season of the year and the global value from Mine1 and Mine2.

Table 3. Comparison of the friction factors per season

	Spring k (kg/m^3)	**Summer** k (kg/m^3)	**Autumn** k (kg/m^3)	**Winter** k (kg/m^3)	**Annual** k (kg/m^3)	**Standard deviation**
Mine1	0,00865	0,00837	0,00878	0,00874	0,00869	0,00024
Mine2	0,00707	0,00687	0,00714	0,00710	0,00704	0,00036
Difference (%)	22,4	21,9	23,1	23,0	23,4	

Although Table 3 displays similar values, in Mine1 are higher than in Mine2 considering all seasons. Thus, airways in the second case will offer better conditions to the air for flowing. In addition, Figure 1 shows the friction factor trend along the year, having higher values in spring and autumn than in winter and summer. This fact could be owing to the geographical zone where mines are placed have a climate with important variation of temperature and humidity in spring and autumn periods, even on the same day, affecting the characteristics of the air and therefore the stability of roofs and walls in the airways; increasing the roughness and subsequently the friction factor values as well.

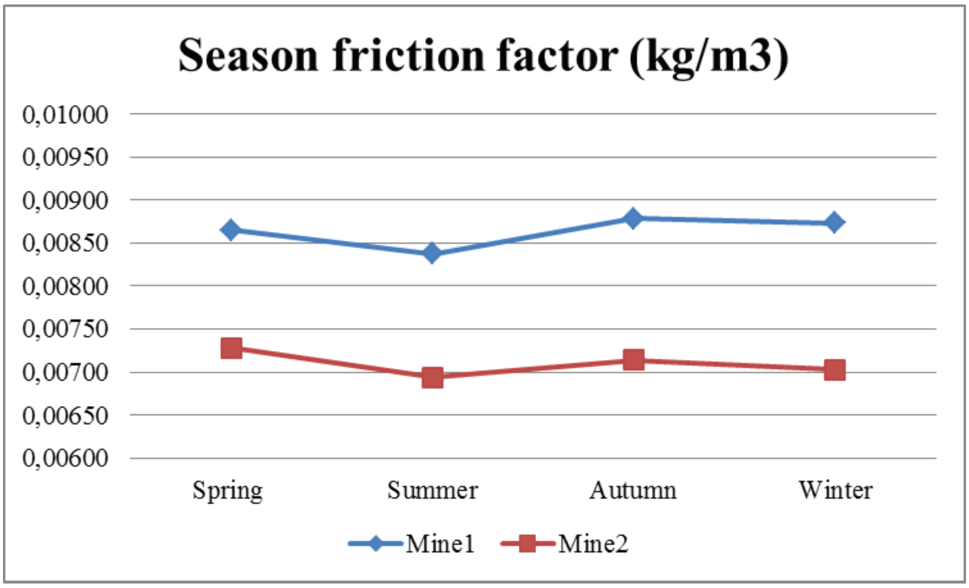

Figure 1. Graph of the friction factor per season.

Since there are no bibliographical information concerning underground potash mining, values obtained have been compared to current parameters from coal and metal mines. As can be noted from Table 4, there is a significant correlation among them in the different types of airways, even though the comparison is done with other sort of mining.

Table 4. Percentage difference between the values obtained and the bibliography values

Airway type	**Potash mine values**	**Difference (%)**		
		Prosser and Wallace (2002)	**McPherson (2009)**	**Hartman et al. (1997)**
Clean Airway	0,0076	-1,32	18,42	5,26
Airway with irregularities	0,00762	14,17	18,11	19,42
Mine Drift	0,01215	-27,57	-1,23	121,40

5.- CONCLUSIONS

Characteristic friction factors in two case studies potash mines using a room and pillar method have been determined. Despite each one has its own characteristics; a framework for future studies related to mine ventilation in this type of exploitations has been achieved. In addition, it can be concluded that roughness of the airways is basically caused by the exploitation method and the nature of the deposit, which has certain deformable properties that affect the shape of the tunnels. Moreover, outside climatic conditions have been proved as a remarkable factor in terms of roughness variation.

ACKNOWLEDGEMENTS

This work was supported by the Iberpotash Chair in Mining Sustainability (UPC). The authors would like to thank the staff of ICL-Iberia for their willingness and contributions to the results.

REFERENCES

[1] I. Duckworth, B. Prosser, Analysis of the Data Obtained from Ventilation Studies of Longwall Panels, Proc. 6th International. Mine Ventilation Congress, (1997) 223–229.

[2] N.I. Alymenko, Aerodynamic Parameters of Ventilating Passages Joined-Up with the Main Mine Fan, Journal of Mining. Science, 47 (2012) 814–823.

[3] A.V. Shalimov, Numerical Modelling of Air Flows in Mines under Emergency State Ventilation, Journal of Mining. Science, 47 (2011) 807–813.

[4] G. McElroy, Engineering Factors in the Ventilation of Metal Mines, Bureau of Mines, (1935).

[5] I.J. Duckworth, I. Loomis, B. Prosser, Fifteen Years of Resistance Data Collected at Freeport Indonesia, Proc. 14th U.S./North American Mine Ventilation Symposium, (2012) 161–166.

[6] K. Fytas, C. Gagnon, A Database of Ventilation Friction Factors for Quebec Underground Mines, Proc. 14th U.S./North American Mine Ventilation Symposium, (2008) 615–622.

[7] B.S. Prosser, K.G. Wallace, Practical Values of Friction Factors, Proc. 8th US Mine Ventilation Symposium, (1999) 691–696.

[8] A.M. Wala, Studies of Friction Factor for Kentucky's Coal Mines, Proc. 5th U.S. Mine Ventilation Symposium, (1991) 675–684.

[9] B. Prosser, K. Wallace, Practical Values of Friction Factors, Mine Ventilation Service, Inc., California, USA, (2002).

[10] C. Montecinos, K. Wallace, Equivalent Roughness for Pressure Drop Calculations in Mine Ventilation, Proc. 13th U.S./North American Mine Ventilation Symposium, (2010) 225–230.

[11] M.J. McPherson, Subsurface Ventilation and Environmental Engineering, Mine Ventilation Services, Inc., California, USA, (2009).

[12] C. Meyer, Determining the Friction Factors for Underground Colliery Board and Pillar Working, Safety in Mines Research Advisory Committee, USA, (1998).