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Tesis

Ventilation System Simulation Model at a Mine

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Ventilation System Simulation Model at a Mine

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Abstract. This research project modeled and simulated a ventilation system at a Mining Concession, obtaining real-time information regarding the fans used to ventilate the mine. The simulation was developed using the VENTSIM 5 software, which also helped define the number of fans and the operating parameters required, field information, mine dimensions, the mining method, production, geothermal gradient, gas emission, air stream, and air pressure. In addition, the results from software operation revealed the need to open chimneys and use fans. Furthermore, the results also suggest that a specialist dedicated to ventilation and fan maintenance must be hired to formalize mining operations as per the Occupational Safety and Health Mining Regulations from Executive Action No. 024-2016-EM as this Mining Concession is currently operating without license.

1. Introduction

Currently, mine ventilation is important because it guarantees favorable conditions for different operating processes. The consumption of explosives, the number of staff members and the gases found in the rock mass owing to mine depth must be controlled by a ventilation system that may guarantee the necessary air stream and speed to maintain an adequate air flow. In addition, this ventilation system must help control suspended dust, maintain temperature within parameters, and sustain oxygen and gases produced by operations within the maximum permissible limits, thus guaranteeing an optimum development of the mining system and operations in the exploration, development, preparation, and underground exploitation processes [1]. The above is in compliance with the provisions from the Occupational Health and Safety Regulation D.S. 024-2016-EM.

The ELMER 70D Mining Concession is developing its underground mining operations at greater depths, which is causing fresh air distribution issues during their operations, thus hindering worker performance and comfort [2].

The absence of a good ventilation study prevents the execution of large and medium projects; therefore, planning and designing an optimal ventilation system is necessary. The Mining Concession does not have ventilation plans in place, which makes it difficult to assess the real problem. Still, the mine has a main fan that does not provide enough air and constantly breaks down as the management does not know how to select a fan for the different tasks and the corresponding specifications to be met. Similarly, the Mining Concession does not have a preventive maintenance program for the fans. The air stream required by the mine has to be dynamic owing to the continuous work of exploitation and penetration and, as they do not have good planning in terms of ventilation, some negative consequences may arise in terms of production and staff members. Under these circumstances, the

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planning and design of a ventilation system in the ELMER 70D Mining Concession is unavoidable. Parameters such as the mining method, equipment, production ratio, gas emission, and temperature will be considered for the design and modeling of the ventilation circuit with support from the VentSim 5.0 Software, which determine the air stream and pressure that needs to be distributed throughout the Mining Concession [3].

2. Literature review

Mines are continually expanding in size and depth, leading to increased dependence on localized subsoil resources. The use of underground auxiliary fans is a preferred method to increase and control airflow in work areas [4].

An impact study was conducted on four gold mines at different levels in southern Africa, named A, B, C, and D respectively. The parameters and instrumentation used therein revealed the need for auxiliary fans. In this research, 33 auxiliary fans were used in these mines, which resulted in the implementation of a complete ventilation network system [5].

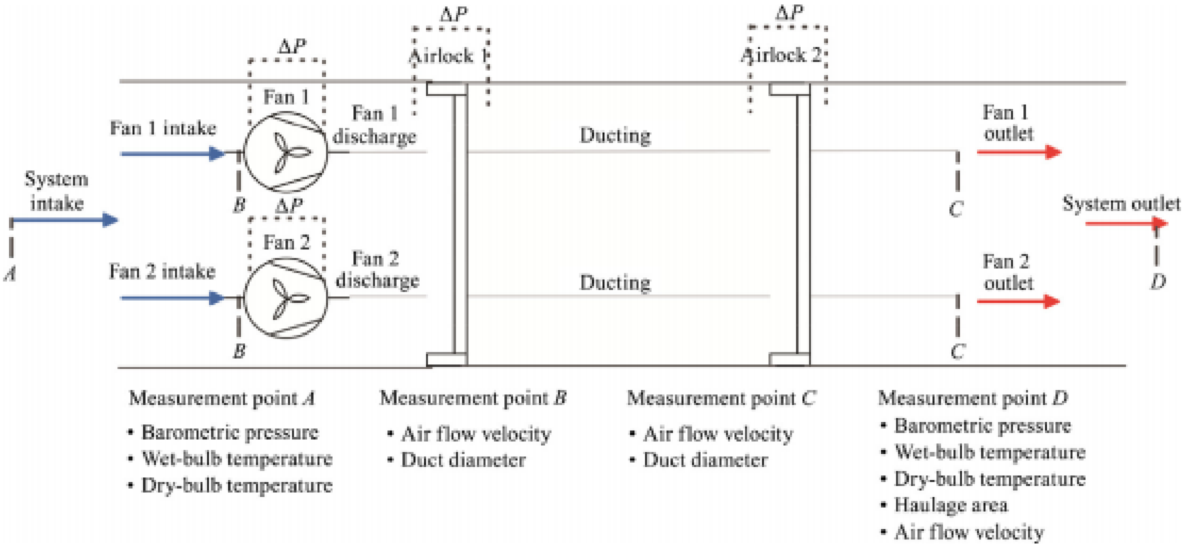

Figure 1. Simulation design of VILLIERES 2019 fans

The ELMER 70D Concession will also deploy auxiliary fans, whose power will be detailed below. In addition, natural ventilation has to be considered, which is the natural moving energy in spite of the geothermal gradient in every underground mine. Therefore, it is ventilation that does not require the use of fans. Mechanical ventilation means that the use of a fan is required to increase airflow; main and secondary ventilation is a ventilation circuit including either Raise Bore, Galleries, or Cruisers. The main fans may be aspirating (when extracting air from the mine) or impelling (when blowing air into the mine). To ensure that all tasks have the amount of air required, redistributing the airflow into the circuit is necessary. One way of achieving this is increasing the resistance of some branch lines through regulators (partitions or doors) or installing secondary fans (boosters). Finally, auxiliary ventilation is used for blind tasks, namely, tasks that have no circuit. The main objective of auxiliary ventilation is to provide, in the front line of work, an airflow enabling the following tasks.

- Adequate dilution of toxic gases.
- Acceptable level of thermal-environmental conditions in the front line of work.
- The air volume required is generally guided through a duct installed inside the task under ventilation. The impelling ventilation is used in our mine, drawing air from the branch of the main network toward the front and then back to the main network from where it was drawn.
- The air shafts in blind tasks must reach a depth of 20 m from the top, thereby providing enough flow to perform the works.

The article by Chang [5] builds a computing model based on physical conditions of a mine front in Western Australia. In the corresponding simulations, the air is considered as non-compressible and

there is no heat transfer based on the study and the gravity, which is 9.8 m/s2. The high-speed air was blown from the exit of the duct and migrated to the direction face in addition to reverse direction airflow after hitting the direction face, and then the apex area between the direction face and the duct head was generated through the combined effect of reverse-direction airflow and the duct air.
For the ELMER 70D Mine Concession, Level 100, the fresh air will not be adequately distributed to shelters, slopes, and sublevels by simply using a compressor and a ventilation shaft because natural ventilation and the method applied do not provide the required level of air. Herein, the VENTSIM 5 simulation software will be used to assess the influence of many ventilation parameters in wind speed, which are of critical in practice [6].

For the development of the ventilation network, a main level of the ELMER 70D Mine Concession will be considered while considering the following as reference: Nv 200 – CX 786, Nv 300 – C 300.
In [7], the author refers to the appropriate design and implementation of mine ventilation systems, which are key to ensure mine worker safety. In this respect, the efficiency and reliability of mine ventilation systems depends on the numeric simulation of various regular and emergency situations in mines. Similarly, it implies the adequate development of mathematics and mine ventilation processes.

3. Contribution

3.1. Main data and calculation

The ELMER 70D Mine Concession is located 4,430 m above sea level; therefore, the air stream will increase 100% to 6 m3/min per person.

When hydrocarbon engine equipment is not used during operation, the total stream must be calculated in accordance with the formula presented below, before being compared against the explosive consumption stream. After obtaining each value, the highest value is determined as the total air requirement. Air demand inside the mine must be calculated under section d), article 252 of the regulation [8], considering the following formula:

$$QT0 = QT1 + QFu \tag{1}$$

Where: QT0 = Total stream for operation, GALLERY, LEVEL 100 and QT1 = The sum of air stream required by:

$$QFu = 15\% \text{ from } QT1 \tag{2}$$

In this sense, the following values must be previously determined.

3.1.1. Stream required by number of workers (QTr)

$$QTr = F \times N \ (m^3/min) \tag{3}$$

Where: QTr = total stream for “n” workers (m^3/min); F = Minimum stream per person according to range set forth in article 247 of the regulation; and N = Number of workers of largest crew on call.
Data: F = 6 m3/min (for an altitude of 4430 m above sea level); N = 20 collaborators.

Table 1. Stream required by the number of workers

Company	No of WORKERS ON CALL	DS 023-2017 EM (me/min)	Stream	
			M3/min	CFM
S.M.R.L. ELMER 70A	15	6	90	3,178
AVG Shaft Technologies S.A.	5	6	30	1,059
	QTr		120	4,237

3.1.2. Stream required by wood consumption (QMa)

$$QMa = T \times u \ (m^3//min) \tag{4}$$

Where:

QMa = stream required by tons of production (m3/min);

u = production factor
T = production in wet metric tons per crew on call.

Table 2. Production factor according to wood consumption

Zone	PRODUCTION TMH/GD	WOOD CONSUMPTION TN/GD	WOOD CONSUMPTION %	PRODUCTION FACTOR N M3/MIN	m3/min	CFM
	0	0	0.00%	0	0	0
	25.23	7.13	6.99%	0	0	0
	12.20	0	3.79%	0	0	0
		Qma			0	0

Data:
u = from 7.3%; therefore, it corresponds to 0 m3/min.; T = 37.53 TM/crew on call.

3.1.3. Stream required by temperature in work tasks (QTe)

$$QTe = Vm \times A \times N \ (m^3/min) \quad (5)$$

Where: QTe = stream on temperature (m³/min); Vm = minimum speed; A = mean task area; and N = number of levels with temperature above 23°C, equal to a 30 m/min value, under range as per third paragraph of section d) in article 252 of the regulation.
Data: Mean temp. is 25°C; speed must be 30 m³/min.; Vm = 30 m/min; A = Mean task area is 6.7 m2

Table 3. Minimum speed of airflow

Zone	Level with 24 to 29°C temperatures	Minimum speed (Vm) DS 023-2017 EM	Area (Aver.)	Stream m3/min	Stream CFM
CUERPOS	0	0	16.7	0	0
ELMER 70D, nivel 100	1	30	6.7	201	7,098
ESPERANZA	0	0	8.4	0	0
	QTr			201	7,098

3.1.4. Stream required by Explosive consumption (QEx)

$$QEx = A \times V \times N \ (m3/min) \quad (6)$$

Where: QEx = air stream required by consumption of detonated explosive (m3/min); A = mean task area (m2); V = minimum speed required by regulation (m/min); and N = number of blasting levels.
Data: QEx = 20 m/min (Air stream required for dynamite); A = 6.7 m2; V = 20 m/min (Air stream required for dynamite); N = 1; and QEx = 6.7 m2 × 20 m/min × 1 = 134 m3/min.

3.1.5. Stream required by leaks (QFu)

$$QFu = 15\% \times QT1 \ (m3/min) \quad (7)$$

Where:
$$QT1 = QTr + QTe + QMa + QEq \quad (8)$$

Table 4. Stream required by leaks

	m3/min	CFM
Q_{Tr}	120	4,237
Q_{Ma}	-	-
Q_{Te}	201	7,098
Q_{Ex}	134	4,732
QT1	455	16,067

Table 5. Stream required by total leaks

QT1 (m3/min)	Min. speed (Vm) DS 023-2017 EM	m3/min	CFM
455	15%	68	2.410
	QFu	68	2.410

Total stream of air requirement:

$$Q_{To} = Q_{T1} + Q_{Fu} \tag{9}$$

The following is required to analyze data and future design of ventilation system (Fig. 2)

Table 6. ELMER 70D air stream requirement

STREAM	m3/min	CFM
QT1	455	16.067
QFu	68	2.410
QT0	523	18.477

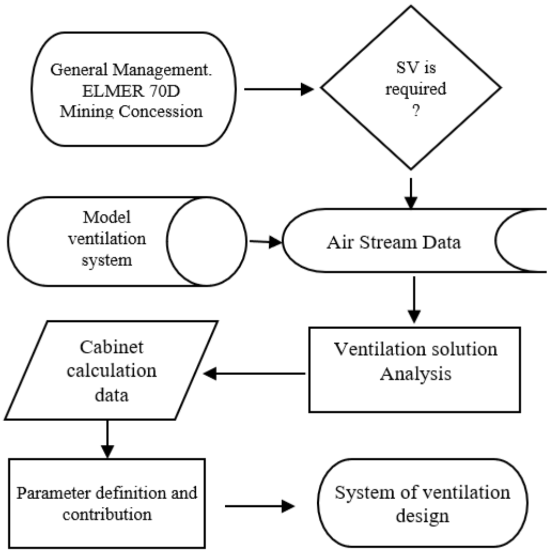

Figure 2. Design of ventilation system

3.2. Valuations of mining exploitation

Table 7. Total inlet of fresh air ELMER 70D

FRESH AIR INLET							
EST.	LEVEL	TASK	ZONE	DATE: 05/15/2019	TEMP. °C	AREA	Speed
				TIME		m2	m/min
EVPI-01	300	BM- 435	ESPERANZA	8:20:00 am	7,2	6,5	38
EVPI-02	100	BM- 435	ELMER 70D -100	9:12:00 am	7,3	6,7	25
EVPI-04	100	BM-ALEX 01	CUERPOS	10:21 am	7,2	7,2	28
STREAM		TOTAL INLET		532,99	18822		

Table 8. Total outlet of foul air ELMER 70D

FOUL AIR OUTLET									
EST.	LEVEL	TASK	ZONE	DATE: 05/22/2019	TEMP. ° C	AREA	SPEED	STREAM	
				TIME		m2	n/min	m3/min	cfm
N-200	SURFACE	RB 593	CHIMENEA	9:21 am	10,2	4,5	12624	238,94	201.575
EVPS-02	SURFACE	RB 131	ELMER 70D 100	9:52 am	11,2	6,7	51372	307,04	184.564
						TOTAL OUTLET		545,98	19282

Table 9. Air covering

AIR COVERING		
	m3/min	cfm
Air inlet	532	18.822
Required stream	523	18.477
Covering (%)	110%	
Surplus (CFM)	345	

4. Results

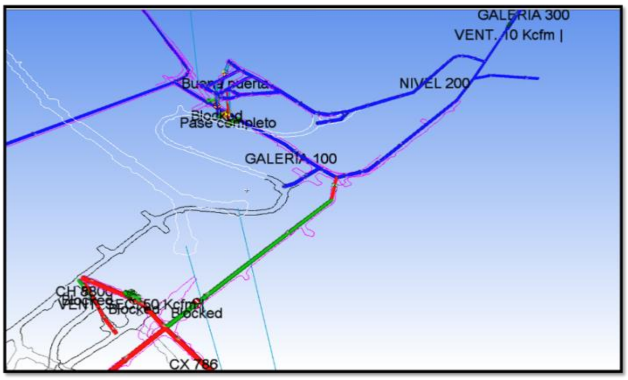

Figure 3. CM ELMER 70D 2019 simulation design

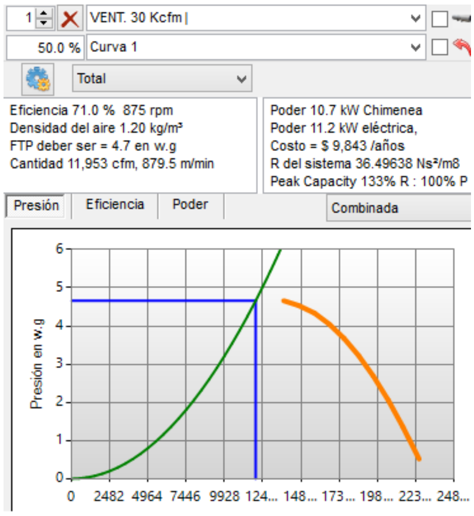

Figure 4. Simulation of CM ELMER 70D air stream

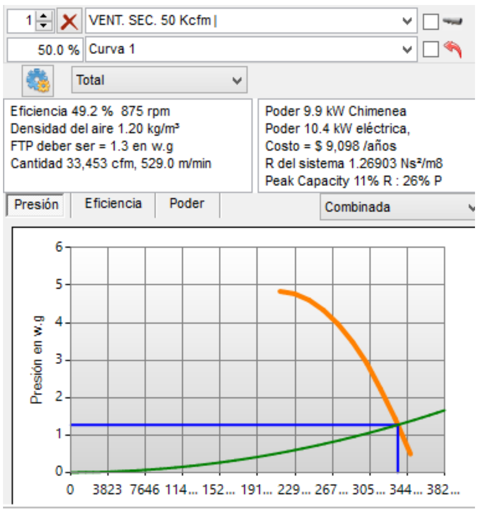

Figure 5. Simulation with N200 air stream upgrade.

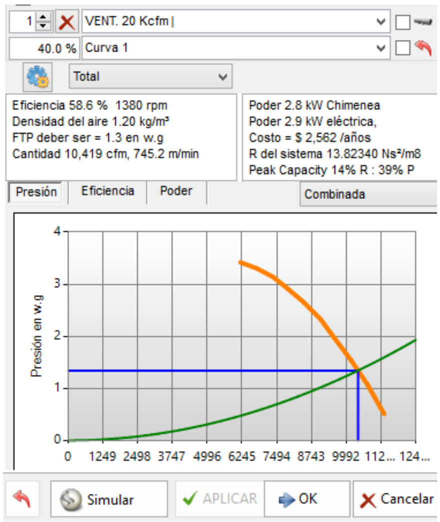

Figure 6. Simulation with N300 air stream upgrade

Level 100 has three chimneys. The first chimney is 200 m deep throughout the entire length of level 100, and it will be a new duct of fresh air inlet as shown in Fig. 3. The second chimney will be closed, no air will be blown into nor extracted from the chimney. The third chimney, which is 100 m from the second one, will be an outlet for foul air as it is connected to the surface.

These chimneys connect levels 100 and 300. There will be an extractor, a 20 kCFM primary fan, in the third chimney. Power results can be observed in Fig. 4.

Level 200 has a secondary fan with an efficiency at the intersection of limits, which is adequate, as shown in the following simulation results.

Level 300 has an auxiliary fan and 53-m long ventilation shafts with efficiency at the intersection of limits, which is adequate, as shown in the following simulation results. In Figures 5 and 6 an improvement in fan stream and power levels can be observed as they are at the corresponding intersection.

5. Conclusions

This study demonstrated the importance of chimneys, which will no longer be used as exhaust pipes but instead exclusively for ventilation. To this end, a main fan, at a capacity of 20 kCFM, will be installed to extract foul air from chimney No. 2

It was also concluded that when the diameter of ventilation shafts is small, there will be less air stream. Therefore, if mining operations expand in the ELMER 70D Mining Concession, a 0.35-m ventilation shaft will be required.

The ELMER 70D Mining Concession does not have a ventilation circuit. Instead, it features a natural draught system that does not allow good airflow. Then, planning a ventilation system for current activity and future advances. For example, both the simulation and cabinet calculations revealed that LEVEL 100 requires an airflow of at least 18477 CFM as the initial fresh air blown into the chimney at 10 kCFM was not effective enough for proper operation performance.

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