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FAN REQUIREMENTS IN THE SECOND 100 YEARS OF A MINE LIFE

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ABSTRACT

The Missouri University of Science and Technology's (Missouri S&T) Experimental Mine is a teaching and research facility which has been excavated in limestone by mining engineering students over almost 100 years. The mine is currently being extended to a second level. Available fans for ventilation are two surface fans of 24 kW and two underground booster fans of 12 kW. The design of a ventilation network in conjunction with multi surface fans and booster fans entails a complex procedure.

Ventsim Visual software modeling has been used for network analysis to determine the optimum surface and booster fans locations, blade settings, and speeds. Both natural and mechanical induced ventilation pressures have been taken into account. Three working faces on each level have been designated as target points that minimum air quantities are required. The model has been calibrated against a pressure and quantity survey.

Design of ductwork, door/stopping positions and different fans characteristics have been examined. The optimum flow rate at identified working faces, efficiency and minimum energy losses and annual network power cost determine the best scenario. The optimum design has been determined for the ventilation network for the next 100 years. The optimum flow rate across working faces is the key criterion selected.

INTRODUCTION

Multiple operating points of mine fans are a problem that fan and mining engineers must constantly be aware of in mine/fan systems.

In a single fan system, unstable conditions can be avoided by restricting fan operation to the "normal operating range."

Unstable oscillating behavior of an axial-flow fan assuming a properly manufactured and installed fan can normally be attributed to the multiple operating points that exist under the given ventilation system configuration. Eck (1973) provided the following explanation for the resulting condition: If these [multiple operating] points are close together [in terms of fan pressures and air quantities], which often happens, then even small pressure fluctuations might initiate oscillation [between operating points]. Once oscillation has been initiated for whatever reason, additional uncontrollable displacements of the characteristic will occur due to the continuous accelerations and delays [pulsing] of the individual air columns. To prevent this, care must be taken that the operating point is at same distance from the critical range (Y. J. Wang, Mutmansky, & Hartman, 1988).

The system operating point in ventilation systems with a single main fan is defined by the intersection of the mine impedance curve, based on Atkinson's equation, the fan characteristic curve. As mining progresses the total resistance is increased and the mine characteristic curve becomes steeper. The operating point then moves up the fan curve, reducing the total air quantity available and increasing the system pressure.

A study has been carried on to improve the ventilation network model of the Missouri University of Science and Technology Experimental Mine that based on use of Ventsim Visual ventilation software. Numerous parameters such as efficiency, air quantity, total pressure, density and temperature have been considered to select the most appropriate surface and booster fans.

Five simulation scenarios have been employed in order to maximize the network efficiency and air flow quantity in three working faces and minimize the annual network power cost.

Different locations for surface fan(s), and booster fan(s) at different blades' angle have been examined in (series/parallel) arrangements. Pressure quantity leap frog surveys have been used to acquire the performance specification of the mine. The main fan selection has been carried out according to the mine performance specification and fans characteristic. The present ventilation network has been made a basic for ventilation network optimization.

MISSOURI S&T EXPERIMENTAL MINE

The Experimental Mine is an underground limestone mine located in Rolla, Missouri. The mine is accessed by two adit portals, has three raises to the surface and two primary ventilation shaft. The two mine portals both have ventilation doors (Figure 1).

Figure 1. The Missouri S&T Experimental Mine portals.

Current ventilation network

The 1.2-m diameter Joy axial vane fan with 30 ~~KW~~ kW motor has been installed to exhausting ~~blowing~~ approximately 23.6 m^3/s of airflow at 1,000 Pa of static pressure to the underground workings. Two Spendrup booster fans have been installed in underground in series connection to the surface fan. Each booster fan is driven by a 12 KW three phase 460V motor that will load the circuit by approximately 20A. Booster fans have been mounted on skids to facilitate transportation. Locations of booster fans can be altered to optimize a particular ventilation network. A variable frequency drive (VFD) has been installed at each fan. The VFD's have been set up in separate boxes next to the switch boxes (Figure 2). Booster fans are of vane axial deign andhave adjustable blade angles.

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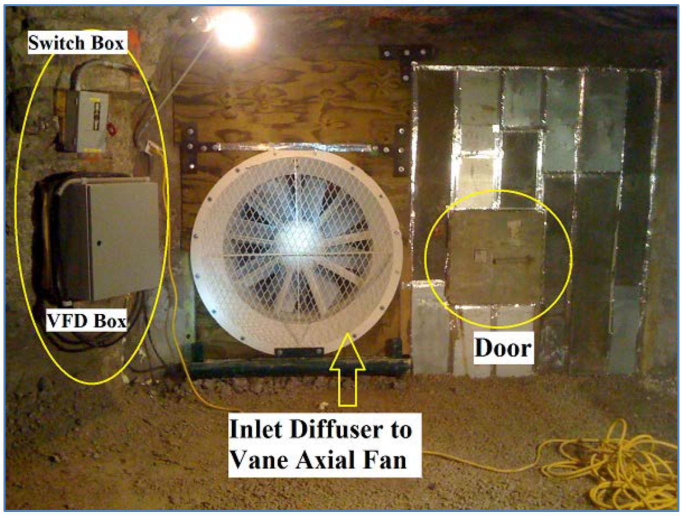

Figure 2. Booster fans components.

CHOOSING SURFACE FAN FOR PRELIMINARY DESIGN PROCEDURES

Choosing a method to supply the resources to meet ventilation requirements involves many considerations. These include:

- cost versus benefit
- reliability
- positional efficiency/flexibility
- installation time
- technology level (Struble, Marks, & Brown, 1988)

Mine ventilation main fan is one of the four major equipments in mine, which keeps running for 24h a day as main ventilation shaft. So it is mine's "breathing" system. It is such an important equipment for safety that it will be a huge threat to safe production if it does not meet the needs of mine production for some reason (Q. Wang & Shang, 2009).

Before the use of any surface fan, alternative possibilities in terms of optimizing the ventilation network had to be considered. To clarify this issue it can be referred to the modification of basic surface fan, transition of surface fan and booster fan(s) in different parts of the mine, airways widening and reformation on louvers, collar's shaft and mounting the VFD on surface fan. The procedures were divided in to 3 main steps: Location of the main fan, pressure- quantity survey, and fan selection.

Location of main fan

In the majority of the world's mines, main fans are sited on surface. In the case of coal mines this may be a mandatory requirement. A surface location facilitates installation, testing, access and maintenance while allowing better protection of the fan during an emergency situation. Sitting main fans underground may be considered where fan noise is to be avoided on surface or when shafts must be available for hoisting and free of airlocks. In designing the main ventilation infrastructure of a mine, a primary decision is whether to connect the main fans to the upcast shafts such as an exhausting system or, alternatively, to connect the main fans to the downcast shaft in order to provide a forcing or blowing system (chapter4 p.5)(Mcpherson,1993).The design of main mine fan installations at underground mines must comply with requirements of the Mine Safety and Health Administration of the United States Department of Labor as outlined in the 30 CFR (Code of Federal Regulations) Part 75 ("Mandatory Safety Standards- Underground coal mines") [3] or part 57 (" Safety and Health Standards – Underground Metal and Non Metal Mines") [4](Gamble, Ray, Americas, & York, 2009). The installation of main mine fans underground is prohibited by 30 CFR part 75.310, (a)(1).

The location of the main fan has been determined on the surface. Various systems such as exhausting system, forcing system, push-pull system in connection with booster fans have been considered in the design by ventsim visual analysis to actualize the optimum model.

Pressure Quantity Survey

The Leapfrog procedure has been employed to determine the mine's specification. Pitot tube traverses have been used to measure both Static pressure (Ps) and Total pressure (Pt) on present surface fan. Pressure transducers have been utilized to take simultaneous readings at successive stations. Dial Vane anemometer has been utilized to measure velocity. The sling hygrometer has been conducted to determine wet bulb temperature, dry bulb temperature, humidity and dew point. So, numerous specification and "k" Atkinson factors have been calculated for each airway. Consequently, three different average "K" factors for main airways, sub main airways and shafts have been applied in all scenarios.

Surface fan selection

The process of finding and ordering the fan often commences with the ventilation engineer perusing the catalogues of fan characteristics produced by fan manufacturers(Mcpherson, n.d.-b). The first consideration was whether to go with centrifugal or axial. Each has been favored in different countries at different times (Struble, Marks, & Brown, 1988).

Not only the calculated and determined mine airflow quantity and total pressure requirements, but also considering over the detailed design of various vane axial fans have been used for choosing the most appropriate surface fan. The Alphair 4500 VAX 1800 full blade single stage JetStream Adjustable Pitch Vane Axial fan has been chosen as the other surface fan that meets the requirements of the mine.

Fan performance information has been gathered in table 1 (Alphire fan manufacturer's characteristic curve). The fan manufacturer's characteristic curve has been shown in figure 3. Ten different fan total pressures have been determined as criteria to calculate other specifications such as quantity, fan total efficiency and absorbed power. All characteristic of the vane axial fan has been embedded in to the Ventsim Visual Program in order to be employed in the design procedure.

Table 1. Performance information (fan diameter: 45).

Volume cfm	FTP In Wg	FSP in Wg	Temp °F	Density lb/ft3	Power HP	Efft %	RPM	Bla Ang Deg	Vfan fpm	Vcone fpm
52965	5.44	4.00	70	0.075	57.7	78.5	1780	18.7	4795.50	4795.50

Model: 4500-VAX-1800 Full Blade Single Stage JetStream Adjustable Pitch Vane Axial Fan

The optimum fan performance curve has been embedded in to the ventsim visual simulator in order to commence designing of the mine's ventilation network (Figure 4).

VENTSIM VENTILATION MODEL

Design criteria

The Alphair 4500 VAX 1800 Adjustable Pitch Vane Axial Fan was simulated in Ventsim to be investigated its interaction with other fans. The Total pressure method has been determined as the type of fan pressure simulation in Ventsim. The airflow Quantity in predetermined three working faces separately and the total Quantity, network annual power cost and network efficiency and the exhaust ventilation system have been considered as an empirical approach to compare 5 scenarios. All scenarios have been investigated according to two different criteria of the highest air quantity and the highest network efficiency and with the lowest network annual power cost.

Models simulation

The major target of Missouri university of science and technology experimental mine ventilation modeling is optimization of ventilation network by improving airflow circuit at working faces and efficiency and diminishing the annual power cost in the whole. At experimental mine the rudimentary results show that the combination of west booster fan and main fan is the best option for optimizing the network(Habibi & Gillies, 2012) (figure 5). The total airflow intake and exhaust in that connection has been measured 19.2 m^3/s with the network low

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efficiency and high Annual power cost. In all scenarios, the changes in location of surface fans with each other and reversed ventilation network have been speculated. The design of surface fans in all scenarios has been determined as the forcing system but the exhausting system has been investigated too.

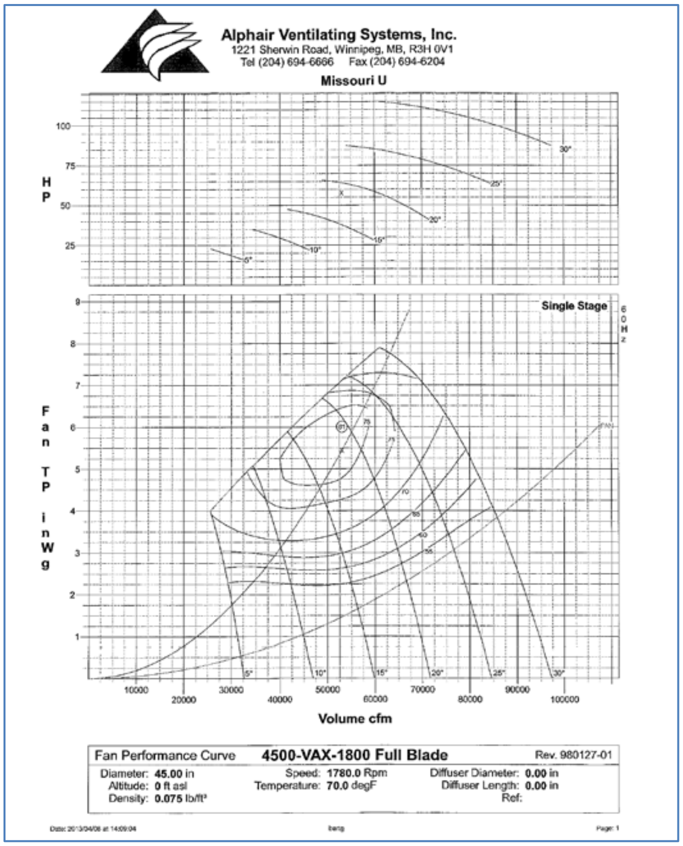

Figure 3. Manufacturer's characteristic curve 4500-VAX-1800 Full Blade.

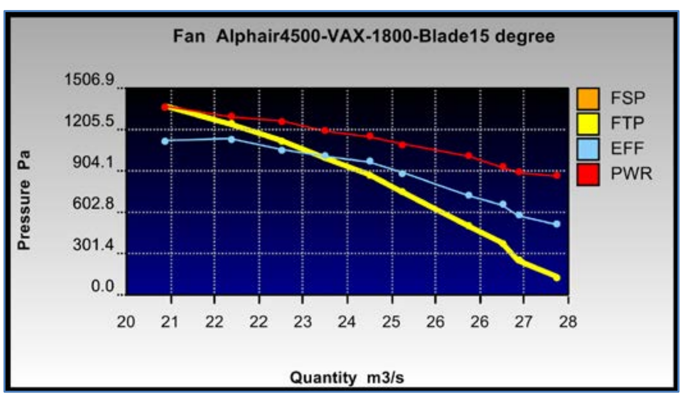

Figure 4. Alphair 4500-VAX-1800-Blade 15 degree.

Scenarios

Scenario 1. The first simulation has been carried out by Alphair 4500 VAX Vane Axial fan in parallel connection with the joy surface fan. The surface fans have been simulated in series connection to the both Spendrup booster fans. The simulation has been followed by changing the locations of booster fans with numerous blades' angles in order to achieve the optimal ventilation network and also the model's network efficiency, annual power cost and Total Air Quantity have been investigated in all three faces. The result has proven that the network efficiency will be enhanced notoriously in conjunction with significant decrease in network annual power cost when at least 15 m^3/s has been obtained for each working face. However this scenario has been examined for obtaining at least 20 m^3/s and 25 m^3/s in each working face (Table 2). The east and west booster fans have been simulated to be deactivated to acquire the optimal result. The negated warning has been appeared when the booster fans have been turned on. Moreover, one stopping must be changed to achieve the minimum requirements of air in working face 2 for at least 25 m^3/s air quantities in all working faces.

Figure 5. Experimental Mine Ventsim Visual model with both booster fans in the network.

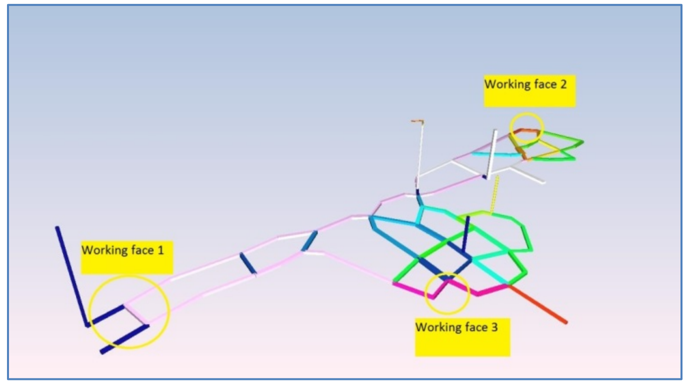

Figure 6. Position of determined working faces.

Table 2. Ventsim Visual result for scenario 1, Criteria: the highest quantity achievement.

criteria	Network Efficiency%	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m3/s	Total Q m^3/s
At least 15	64.7	8451	22.9	16.1	21.1	60.1
At least 20 m^3/s	52.4	27,715	30.8	21.6	28.3	80.7
At least 25 m^3/s	52.5	27,694	30.8	32	28.3	91.1
Reversed	39.6	30,691	29.2	20.5	26.8	76.5

The speed of Alphair 4500 has been changed from 100% to 60% to achieve the most efficient circuit for this scenario. The exhaust system has been investigated The results have been gathered in table 3.

Table 3. Ventsim Visual result for scenario 1, Criteria: the highest efficiency.

criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m3/s
Most efficient	64.7	8257	22.9	16.1	21.1	60.1
Most efficient reversed Flow	49	9307	21.6	15.2	19.9	56.7

Scenario 2. The second scenario has been shown in figure 4. Experimental mine ventilation network has been divided in to 2 east and west panels independently. The surface fans have been simulated in the same fan house. The result has been shown that total airflow and network efficiency in comparison with the rudimentary design has increased dramatically by adding the new surface fan in the west part of the mine when east booster fan is on and west booster fan is deactivated. In addition, the place of east booster fan has been changed from exhaust air way to the fresh air way in order to achieve the highest air quantity at working face 2. However, the annual power cost has decrease slightly in comparison with the other parameters. The new place for east booster fan with blade #5 has simulated in series connection to the surface fan. However by simultaneous usage of west and east booster fans or the single west booster fan with the other blade angles the efficiency of the mine will be plummeted (table 7.)

In this scenario, at least 25 m^3/s air quantity in all working faces has not been achieved. So, this scenario has not met the minimum requirement of air quantity of the mine. The most efficient situation has been achieved when the both east and west booster fans were deactivated and the speed of Alphair Axial fan has been decreased to 60% of its total speed table 5.

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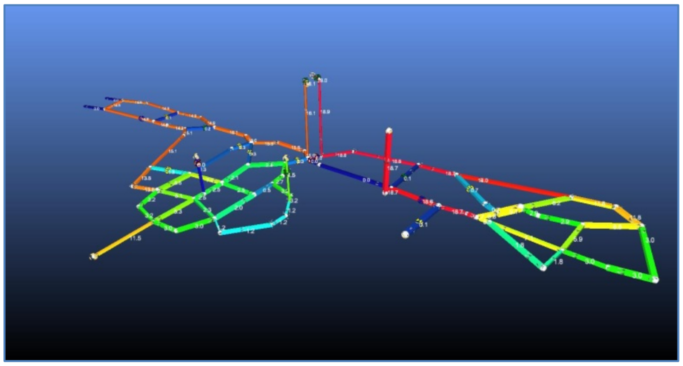

Figure 7. Experimental mine Ventsim Visual Model- scenario2.

Table 4. Ventsim Visual result for scenario 2, Criteria: the highest quantity achievement.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
At least 15 m^3/s	41.4	24704	24.6	17.8	22.9	65.3
At least 20 m^3/s	43.3	25689	24.6	24.9	22.9	72.4
Reversed	25.4	34749	22.7	18.3	21.2	62.2

Table 5. Ventsim Visual result for scenario 2, Criteria: the highest efficiency.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
Most efficient	52.9	7878	14.8	11.8	13.8	40.4
Most efficient reversed flow	27.6	16139	18.2	18.3	15.7	52.2

Scenario 3. The third scenario and the location of surface fans have been plotted in figure 8. The parking shaft has been selected as the exhaust shaft for the west panel. The network efficiency & total airflow in comparison with the rudimentary ventilation network have been experiencing the sharp increase. On the contrary the network annual cost has been soared up slightly. 2 spendrup booster fans with different blade' angles in series connection to the surface fans have been made inquiry for different possibilities of the model. The optimal model has been designed with the activated booster fans with blade no 5. The optimum design has been chosen to be compared with other scenarios (Table 6). A tight stopping has been added to the ventilation network to meet the minimum requirements. For air quantity 20 m^3/s and above the simulation has been faced to the low pressure warnings at both booster fans but simulation has been designed successfully.

Table 6. Ventsim Visual result for scenario 3, Criteria: the highest quantity achievement.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
At least 15 m^3/s	48.5	26935	24.3	17.7	22.6	64.6
At least 20 m^3/s	49	27,699	24.3	24.9	22.6	71.8
At least 25 m^3/s	48.5	28206	25.1	25	25.2	75.3
Reversed	31.6	35258	25	23.9	23.2	72.1

Although, the most efficient circuit has been achieved by turning the booster fans off in the west and east panels, the air quantity minimum requirements has not been met (table 7).

Scenario 4. In the fourth scenario the Alphair 4500 VAX Vane Axial fan has been located in the farthest west point of the mine (figure 9). The location of booster fans and their blades angles have been varied in order to attain the best connection to the main fans. The transition in surface fans locations have been considered as an option for the model (table 5). The optimal design has been selected to be compared to the other scenarios.

For minimum air quantity acquiring, east booster fan must be turned on and west should be deactivated. The result has been gathered in table 8.

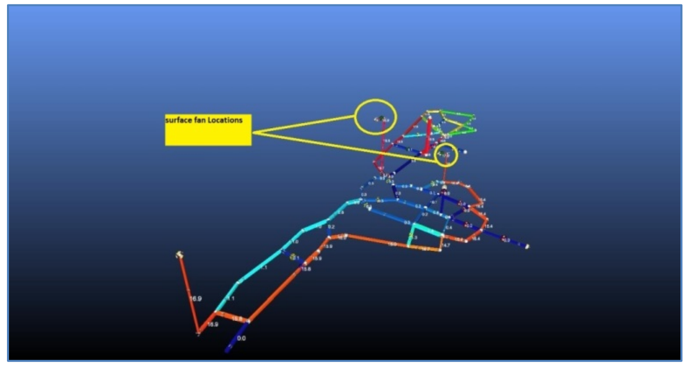

Figure 8. Experimental mine Ventsim Visual Model- scenario3.

Table 7. Ventsim Visual result for scenario 3, Criteria: the highest efficiency.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
Most efficient	54.5	9836	15.8	11.9	14.7	42.4
Most efficient reversed flow	31.4	19853	21.2	12.2	18	51.4

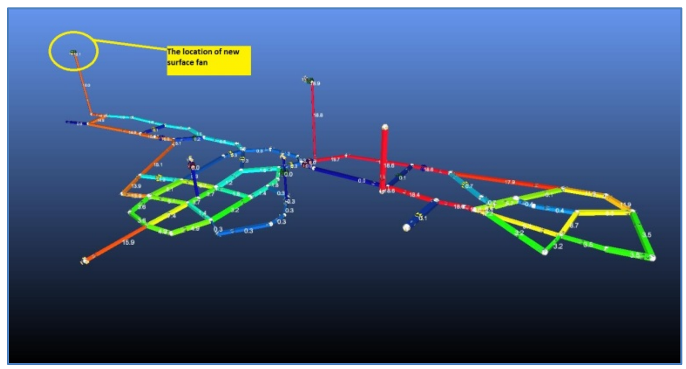

Figure 9. Experimental mine Ventsim Visual Model- scenario 4.

Table 8. Ventsim Visual result for scenario 4, Criteria: the highest quantity achievement

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
At least 15	53.6	8013	15.4	17.7	15.5	48.6
At least 20	47.1	14668	20.5	22.4	20.6	63.5
At least 25	43.5	26100	25.6	25	25.7	76.3
Reversed	26.5	33897	23.7	23.9	23.8	71.4

By turning two booster fans off, the most efficient model has been accomplished in this scenario, for the most efficient exhausting system booster fans must be turned on though. The results of Ventsim visual has been flocked in table 9.

Table 9. Ventsim Visual result for scenario 4, Criteria: the highest efficiency.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
The most efficient	53.3	7992	14.9	11.9	13.9	40.7
The most efficient reversed	27.4	16623	17.9	12.5	15.8	46.2

Scenario 5. The fifth scenario has been illustrated in figure 10. Surface fans have been installed in east and west shafts as same as scenario 3. The east booster fan [in series connection to the main fan] has been employed in the model to optimize the ventilation network. However, the west Spendrup booster fan has been turned off. The result has been drafted in (table 10.) in all working faces at least 25 m^3/s has not been achieved.

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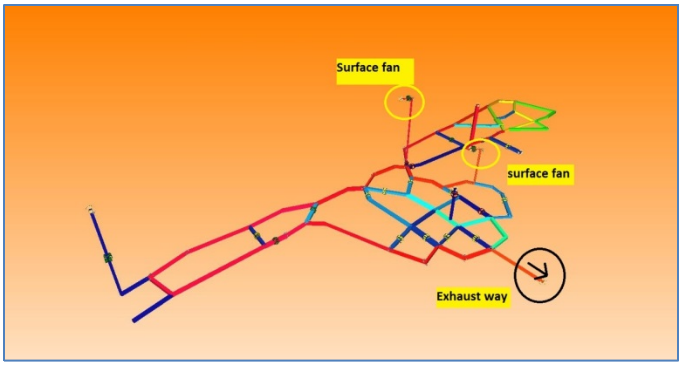

Figure 10. Experimental mine Ventsim Visual Model- scenario 5.

Table 10. Ventsim Visual result for scenario 5.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
At least 15	50.9	9171	19.1	17.7	18.3	55.1
At least 20	44.2	19829	21	25	21.1	67.1
reversed	26.6	34346	24.9	24.3	23.9	73.1

For the optimum efficiency, west booster fan must be run however the east one must be turned off. The most efficient design and the exhausting system of that has been manifested in table 11.

Table 11. Ventsim Visual result for scenario 4, Criteria: the highest efficiency.

Criteria	Network Efficiency %	Network annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Total Q m^3/s
The most efficient	50.9	9166	19.1	11.8	18.3	49.2
The most efficient reversed	29.6	15.114	18.5	15.8	17.7	52

Note: In the most efficient reversed, 2 booster fans are on.

CONCLUSION

Main fan(s) as the heart of the mines' ventilation network plays a key role to supply the needful airflow for the mine. Multi-objective study has been recruited to optimize the air flow rate in the experimental mine's airways. For comprehensive optimization of air flow in all mines of the world, abundant feasible approaches have been considering but improving surface fan(S) as the drastic approach has been preferred from amongst choices.

At Experimental mine ventilation simulation the results manifest that by using parallel connection of surface fans instead of the rudimentary one, the network will be improved drastically. However, it is not the optimum design. Because, the shaft is extremely jagged and it is inappropriate for using for parallel connection. Moreover, on a count of gigantic amount of leakage across louvers and in that 90 degree elbow it won't be recommended to be used. The exhaust system (possible location of main fans) of all scenarios has pin pointed that flow rate and efficiency will be decreasing noticeably rather than the forcing system. By scrutinizing over last 5 scenarios, the upshot has shown that by dividing the experimental mine into 2 different ventilation networks and main fans, the optimal possibilities will be achieved.in scenarios 2 and 5 the minimum requirement interms of at least 25 m^3/s in all working have not been accomplished. Hence, these scenarios have not been considered as the optimum designs. In scenarios 3 and 4 two surface fans with less pressure, they generate higher amount of air quantity. So, scenarios 3 and 4 have been chosen as the optimal scenarios for experimental mine ventilation network. With perusing over the network efficiency, amount of air quantity in all working faces, annual network power cost and the exhausting system, scenario 4 has been designated as the optimum design for ventilation network of experimental mine. Different blade settings of booster fan has been applied in the design to achieve the best combination of surface fan(s) and booster fan(s).By mounting new surface fan and subdividing the ventilation network into two segregated networks, the feasibility of various designing has been expanded.

NEXT 100 YEARS OF EXPERIMENTAL MINE

The Missouri University of Science and Technology experimental mine ventilation draft has been simulated according to the progress scheme for the next 100 years. The optimum scenario has been selected as the criterion for the designing of mine's future ventilation network. Six working faces have been preferred amongst choices as working faces for investigation of air quantity at those spots (figure 11). 4 scenarios have been investigated with different number of surface fan(s), booster fan(s) and numerous blade settings. In all scenarios, forcing system and exhausting systems have been checked into thoroughly. Both natural and mechanical induced ventilation pressures have been taken into account.

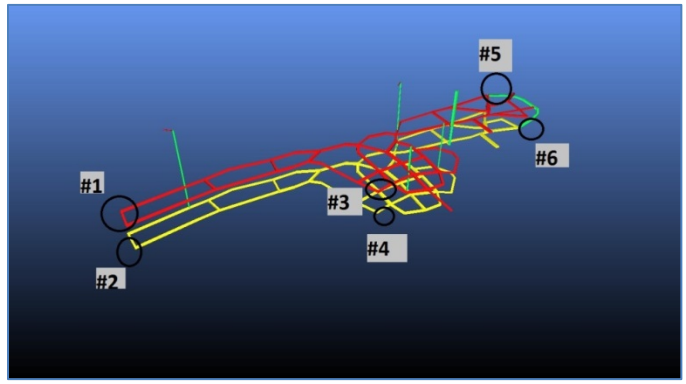

Figure 11. The position of working faces.

Scenarios

Scenario 1. in this scenario the surface Alphair 4500 Vane axial fan has been selected as the only surface fan. All other fans have been turned off. The operating point shows that the fan produces the highest quantity of the air with very low pressure. Three new tight stoppings have been embedded to achieve the highest amount of air in those working faces. The new portal has been designed in the down level of the mine not only for the drainage of water from east part but also makes an easy access to the bottom level. This scenario does not meet the minimum requirements of air quantity in predetermined working faces. The results of forcing and exhausting systems have been flocked in tables 12.

Table 12. Single surface fan results.

System	Network Efficiency %	Network Annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Q4 m^3/s	Q5 m^3/s	Q6 m^3/s	Total Q m^3/s
Forcing	34.5	21,255	13.3	10.7	11.9	9.5	21.9	21.8	89.1
Exhausting	24.3	24,577	11.9	10.5	10.6	9.4	20.3	20.3	83

Scenario 2. This scenario has been plotted in figure 12. The surface Alphair 4500 Vane axial fan has been simulated on main shaft in the center of ventilation network and the joy axial fan has been located on the new parking shaft. The fan curves have been shown that with the low amount of pressure, the highest amount of air quantity has been generated. Five new stoppings doors and two tight steel doors have been added to the network in order to be achieved the highest air quantity in all working faces. Two booster fans have been deactivated.

The results of blowing and exhausting systems have been illustrated in table 13.

Scenario 3. In this scenario, two surface fans and one booster fan have been used in the ventilation network. All blades for booster fans in various air ways of the mine and different speed of surface fans have been examined to achieve the optimum draft (figure 13). The Spendrup booster fan has been located in west part of the mine in upper level. Blade No 5 has been selected as the most effective blade angle for providing enough air quantity in all working faces.

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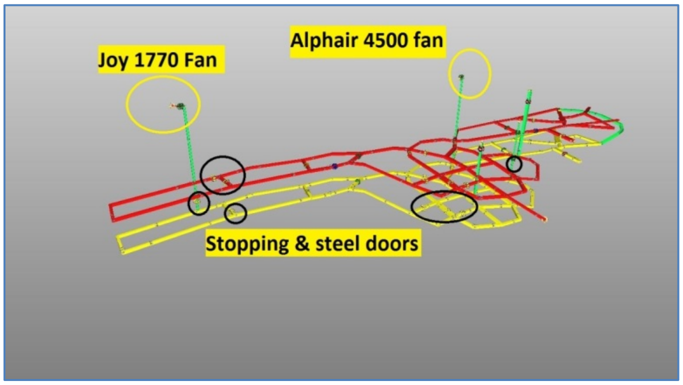

Figure 12. Position of surface fans, stoppings and Steel doors.

Table 13. Bi-surface fans results.

System	Network Efficiency %	Network Annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Q4 m^3/s	Q5 m^3/s	Q6 m^3/s	Total Q m^3/s
Forcing	24.7	46,700	18.5	21.3	16.6	18.8	20.7	20.7	116.6
Exhausting	18	52,250	17.3	20.1	15.5	17.7	19.3	19.3	109.2

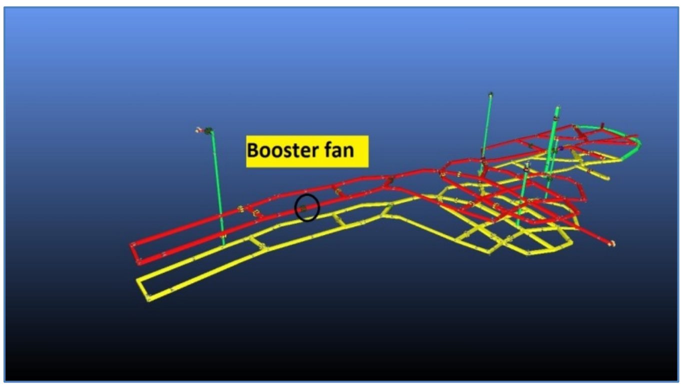

Figure 13. The position of Spendrup booster fan.

The blowing and exhausting data have been gathered in table 14.

Table 14. 2 surface fans and a booster fan results.

System	Network Efficiency %	Network Annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Q4 m^3/s	Q5 m^3/s	Q6 m^3/s	Total Q m^3/s
Forcing	28	46,965	21.9	20.9	19.4	18.4	20.3	20.3	121.2
Exhausting	19.7	54,208	20.3	19.4	17.9	17.1	18.8	18.8	112.3

Scenario 4. 2 surface fans and 2 spendrup booster fans have been utilized in this scenario (figure 14). Different blades of booster fans in various air ways and numerous speeds of surface fans have been taken into account to achieve the optimum design for the network. All surface fans and booster fans generate high air quantity in low pressure. In this design, the steel door in west shaft has been eliminated from the ventilation network.

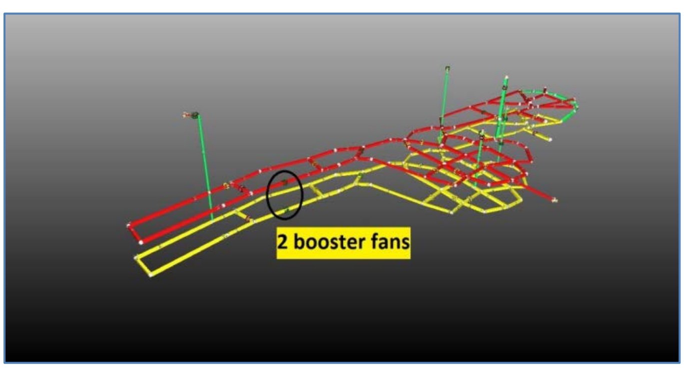

Figure 14. The position of 2 surface fans and 2 booster fans.

The results have been gathered in table 15.

Table 15. 2 surface fans and 2 booster fans results.

System	Network Efficiency %	Network Annual Power cost $	Q1 m^3/s	Q2 m^3/s	Q3 m^3/s	Q4 m^3/s	Q5 m^3/s	Q6 m^3/s	Total Q m^3/s
Forcing	26.4	49,634	25.3	24.8	21.2	20.3	24.6	24.5	140.7
Exhausting	19.9	56,707	24.6	24.2	20.4	19.7	23.8	23.8	136.5

CONCLUSION

Numerous facts and figures derived from this survey have shown that by adding each fan to the network, the amount of air quantity has been ameliorated noticeably. In scenario 1, the minimum requirement (at least 15 m3/s) air quantity in all working faces has not been met. The target has been clarified at least 20 m3/s in all six working faces. Although scenarios 2 and 3 meet at least 15 m3/s air quantities in working faces, they haven't met 20 m3/s in target points. By adding 2 booster fans in the ventilation system, the amount of air quantity has been altered dramatically and also the network efficiency has been improved notoriously. The optimum location of booster fans has been determined in line with achieving the optimum draft for ventilation network. By getting glimpse over tables, it will be clarified that network efficiency with using one booster fan in the circuit in forcing system is higher than utilization of two booster fans. However, it is vice versa in the exhausting system. The network annual power cost in scenario 4 in comparison with this issue in others scenarios doesn't have a significant changes, the amount of air quantity has a noticeable aberration though. So, the amount of air quantity, network efficiency and the network annual power cost determined that fourth scenario as the optimum draft for the ventilation network for the next 100 years.

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