AN ANALYTICAL METHOD FOR DETERMINING THE MINE FIRE LOCATION IN UNDERGROUD MINE

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ABSTRACT

Mine fire poses a serious threat to the safety of all underground personnel. The early determination of the fire location in an underground mine would to a great extent reduce the risks associated with the escaping miners, fire fighters and rescuers. The traditional method used for determining the fire location is fire bossing, systematic inspection of mine workings. However, some major shortcomings exist with this method. These shortcomings include the long time used in the searching, high risk encountered by the inspectors and low successful rate. To overcome these shortcomings, an analytical method and the associated computer program have been developed.

1.INTRODUCTION

To determine the mine fire location, the most frequently used method is to carry out a systematic inspection of all upstream airways from where the smoke is being seen. Because of the low efficiency, high risk and low successful rate associated with this method, a better method has always been searched. In all the efforts toward this aim, the method proposed by the Bureau of Mines seems to be more promising[1]. The principle of the method is to calculate the alarming time pattern for each potential fire source and compare it with the actual alarming time pattern. If the calculated alarming time pattern matches with the real one, then the location of this fire is determined as the real fire location. The logic of the Bureau of Mines' method is correct. However, the fire characteristics of the potential fire sources, the ventilation dilution effect and the properties of the sensors have not been taken into account in the determination of the alarming times and the resultant alarming time pattern. When the intensities of the fire are low or the ventilation dilution effect is large or the sensors are not sensitive enough or any combination of the above three cases, a calculation error may incur. To overcome this limitation, a new method and the associated computer program have been developed. The details of the new method and the program are dealt with below.

2. ALGORITHM

The fire location algorithm of the new method is illustrated in Figure 1. As shown in Figure 1, the general procedures of the method can be summarized as follows:

- Provide the input information. The input information includes mine network configuration and airflow data; contaminant production characteristics of the potential fire sources; locations of the deployed sensors and their alarm thresholds and the actual alarming time pattern.

1. Flame propagation and pressure development within the model are inter-related and consistent .
2. Flame duration within the model is dependent on the ignition position.
3. Flame propagation for the ignition along the symmetry line is symmetrical in the early stages and no effects due to the buoyancy is observed.

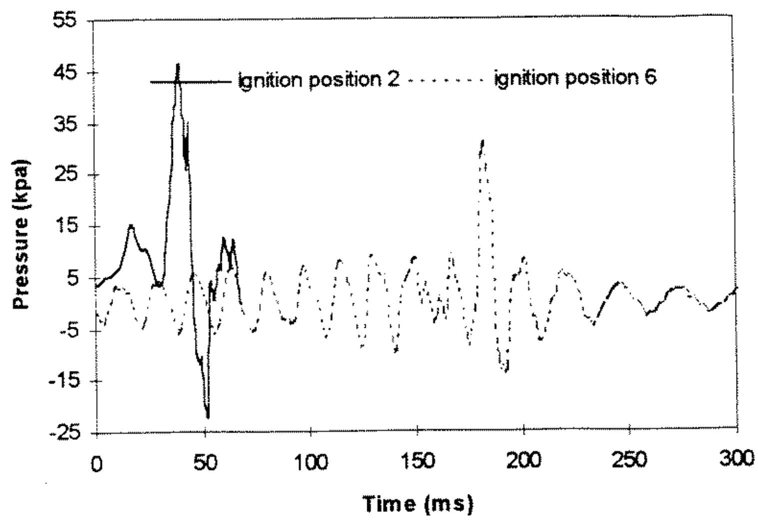

Figure 4 pressure time histories of the same sample point for two ignition position along the model's symmetry line

REFERENCES

1. Maremonti, M., Russo, G., Salzano, E. and Tufano, V. " Numerical Simulation of gas explosions in linked vessels", *J. Loss Prev. Process Ind.*, No.**12**, pp. 189-194, 1999.
2. Holbrow, P., Lunn, G. A. And Tyldesley, A., "Dust explosion protection in linked vessels: guidance for containment and venting", *J. Loss Prevention in the Process Industries*, No.**12**, pp. 227-234, 1999.
3. *"Mine Explosion tests"*, Lake Lynn Experimental Mine, US Bureau of Coal Mines.
4. *Explosion at the Endeavour Colliery at 28 June 1995, Summary of Investigation*, Department of Mineral Resources, New South Wales, MDG No. 1007, May, 1996.
5. Green, A., Nehzat, N., "An integral length scale model for simulating gas explosions", *Proceedings of The Second Asia-Pacific conference on combustion (ASPACC-99)* in Taiwan, pp. 583-585, May 1999.
6. Green, A. R., Piper, I. and Upfold, R. W., "Numerical simulation of gas deflagration using massively parallel processing", *25th Int. Conference Safety in Mines Research Institutes*, 1993.
7. Piper. I., "*Computer simulation of explosions in coal mines using massively parallel processing*", PhD thesis, University of wollongong, 1993.
8. Nehzat, N., *"Gas explosion modelling for the complex geometries"*, PhD. Thesis, The University of New South Wales, Sydney, Austalia, (1998).

- Identify fire zones. According to the alarming time patterns, the potential fire sources can be grouped into different fire zones.
- Determine the fire location Comparing the actual alarming time pattern with the calculated alarming time patterns, if the two patterns match each other, then it can be inferred that the fire will be located in the fire zone whose alarming time pattern matches the actual alarming pattern.

3.APPLICATION EXAMPLE

To demonstrate the use of the location algorithm, an application example for the ventilation network shown in Figure 2 is given below.

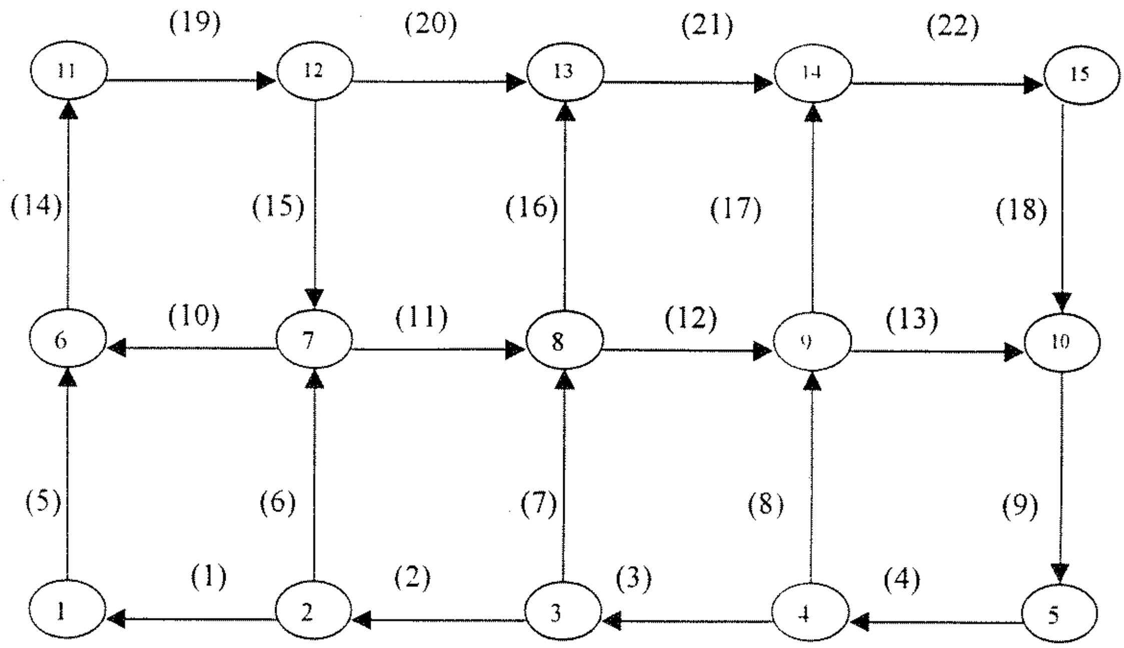

Figure 2 A Simplified Mine Ventilation Plan

It is assumed that the combustion product production rates for the potential fire sources in the network are same and equal to 200 cfm. There are three sensors deployed in airway 13,22 and 14, and the sensors' alarm thresholds are set at 20 ppm According to the given ventilation data for the simplified ventilation plan, the alarming times and the resultant alarming time patterns have been obtained and shown in Table 1. As shown in Table 1, the alarming time patterns of the three sensors in airway 13,22 and 14 divide the whole network into 10 fire zones, that is zone 1 including airway 1, 5, 10, 14 ; zone 2 containing airway 2; zone 3 containing airway 3; zone 4 consisting of airway 4, 9, and 18; zone 5 including airway 6 and 15; zone 6 containing airway 7 and 11; zone 7 made up by airway 8 and 12; zone 8 containing airway 13; zone 9 consisting of airway 16,17,20, 21 and 22; zone 10 containing airway 19. If the actual alarming time pattern is [1.11,64.36], then it can be inferred that the fire location will be in zone 4, which consists of airway 4, 9 and 18.

- Calculate the alarming times of the sensors An iterative method is used to calculate the alarming time of each sensor for a potential fire source. The procedures involved in this method are explained as follows. First, set time T_0 =0 and select a time interval, then determine the sensor's concentration at the time $T_1 = T_0 + dt$ by using the real time concentration predicting method [2]. If the concentration is less than the alarm threshold, then increase the time T_1 by one increment and repeat the concentration calculation until a time T_1 can be found so that the concentration of the sensor at this time is larger than or equal to the specified sensor alarm threshold. Then we will know the exact alarming time must fall within time T_1-dt and T_1. If dt is less than or equal the specified calculation accuracy, then the alarming time can be approximated as T_1. Otherwise, let dt = dt/10 , $T_0 = T_1$-dt, and then repeat the above iterative procedure until the calculated alarming time meets the accuracy requirement.

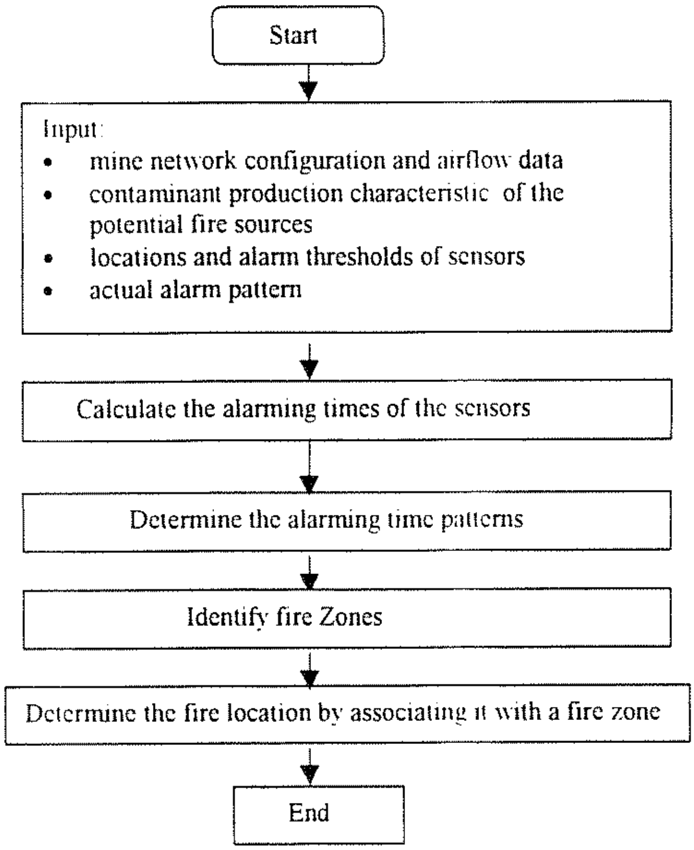

Figure 1 Fire location Algorithm

- Determining the alarming time patterns. Because the actual alarming time pattern is expressed by a list of relative alarming times, the calculated alarming times for each potential fire source need to be transformed into the corresponding relative alarming time pattern. This can be done by deducting the calculated alarming times from a reference alarming time.

Table 1

Airway Number	Start Junction	Finish Junction	Airflow Rate(ft^3)	Airway Length(ft)	cross-sectional Area(ft^2)	Alarm Times (13.22.14)	Alarm Pattern [22-13.14-22]
1	2	1	2355	2000	54	[159.15.140.03.50.81]	[-19.12.-89.22]
2	3	2	5615	2000	54	[98.51.87.22.70.04]	[-11.29.-17.18]
3	4	3	13783	2000	54	[45.33.34.05.77.89]	[-11.29.43.83]
4	5	4	43488	5000	54	[18.62.19.73.84.09]	[1.11.64.36]
5	1	6	2355	200	36	[113.29.94.17.4.95]	[-19.12.-89.22]
6	2	7	3259	200	36	[79.27.68.00.78.27]	[-11.29.10.27]
7	3	8	8168	200	36	[37.50.26.22.110.81]	[-11.28.84.59]
8	4	9	29706	200	36	[12.42.13.52.96.67]	[1.10.83.15]
9	10	5	43488	200	36	[18.79.19.90.84.26]	[1.11.64.36]
10	7	6	1456	2000	54	[184.41.165.29.76.06]	[-19.12.-89.22]
11	7	8	2670	2000	54	[77.06.65.79.150.37]	[-11.27.84.58]
12	8	9	4418	2000	54	[36.62.37.72.120.88]	[1.11.83.16]
13	9	10	22186	5000	54	[12.17.32.07.96.43]	[19.90.64.36]
14	6	11	3812	200	36	[110.24.91.11.1.89]	[-19.12.-89.22]
15	12	7	867	200	36	[85.37.74.09.84.37]	[-11.28.10.28]
16	8	13	6420	200	36	[44.45.25.33.109.93]	[-19.12.84.60]
17	9	14	11937	200	36	[32.40.13.28.97.88]	[-19.12.84.60]
18	15	10	21302	200	36	[19.12.20.24.84.60]	[1.12.64.36]
19	11	12	3812	2000	54	[108.35.89.23.112.7]	[-19.12.23.47]
20	12	13	2944	2000	54	[80.03.60.89.145.48]	[-19.14.84.59]
21	13	14	9365	2000	54	[43.33.24.21.108.81]	[-19.12.84.60]
22	14	15	21302	5000	54	[31.80.12.67.97.27]	[-19.12.84.60]

4. CONCLUSIONS

An analytical method and the associated computer program for determining the mine fire location have been developed. An example has also given to demonstrate the applicability of the method. Compared with the Bureau of mines' method, the calculated alarming times and the resultant alarming time patterns are more accurate because the fire characteristics, ventilation dilution effect and the sensors' properties have been taken into account in the process of determining the alarming time patterns. The major limitation of the method is that the fire location may not be unique if the corresponding fire zone contains more than one airway.

5. REFERENCES

[1] John C. Edwards, Fire Location Model, US Bureau of Mines, Information Circular, pp1-8.

[2] Tan Zhenxiang, A.R.Green &Jean Cross, April 1999, a Prolog Program for Predicating the Concentration of Combustion Products in Mine Ventilation Network, the First international Conference on the Practical Application of Constraint Technology and Logic Programming, London, pp399-413.