Abstract: When the location and intensity of the source of the explosion is determined, the severity and impact of the explosion can be analyzed and predicted, such as the overpressure, temperature, and toxic gas propagation. In order to provide the theory of emergency rescue work, improve rescue efficiency, to protect the safety of rescue personnel. In addition, to determine the gas explosion source location and intensity of the accident investigation also has an important role, on the one hand, it helps to determine the accident-related responsible person, on the other hand, it also can more accurately judge the nature of the accident and the cause of the explosion, summarize the accident experience, for the future prevention of such accidents provide guidance experience. Therefore, the location and intensity of the source of the explosion through the field data inversion is of great significance. Based on Genetic Algorithm (GA, similarly hereinafter) to improve the back propagation (BP) neural network theory, the use of the method through the gas explosion experiments and simulation of overpressure data inversion of roadway gas explosion source location and intensity, the establishment of roadway gas explosion disaster inversion model for emergency rescue and accident investigation to provide data support.

Keywords: Explosion source location; Explosion source intensity; GA-BP; Disaster reversion
Underground mining accounts for 95% of coal mining in China. Due to the complex geological conditions, major disasters and accidents occur from time to time in the process of coal mining, and according to statistics, among these accidents, gas explosions occur most frequently, and their hazards and losses are also the most serious. The risk factors of gas explosion mainly include three aspects: high temperature flame front, overpressure shock wave and the toxic and harmful gases produced after the explosion [1-3]. Among them, the impact of over-pressure shock waves leads to changes in the roadway environment, such as roadway roofing, equipment damage or mobile, toxic gas concentration distribution and ventilation system damage, etc. In brief,

Emergency rescue work needs to analyze to determine the explosion scene in the shortest possible time, which determines the location and intensity of the gas explosion source is the top priority.

Lin et al. conducted an in-depth study on the positive feedback of combustion waves and shock waves and the influence of explosion reflection waves on flame propagation, and found that with the increase of propagation distance, the time difference between combustion waves and shock waves is also shortened, and the equation of the relationship between shock waves and flame propagation is obtained, in addition to the fact that solid wall reflection waves can make the flame form a secondary acceleration, and if the intensity of the reflection waves is high, the flame will be extinguished [4-5]; Kindracki et al. outlines an experimental study of influence of the ignition position and obstacles on explosion development in premixed methane-air mixtures in an elongated explosion vessel [6]. Qu et al., Zhou et al. and Wang et al. and others through the three conservation laws and the explosion of gas dynamics theory of gas explosion shock wave attenuation law to study, found that the shock wave overpressure and propagation distance and cross-sectional area is inversely proportional to the initial explosion energy, and derived shock wave propagation of the finite distance formula and overpressure with the distance of the attenuation formula [7-9]; Lebecki et al. discussed the formation of pressure waves and the conditions for transforming shock waves by analyzing the phenomena in coal dust explosions [10]; Pang et al. used experiments and numerical simulations to study the impact of roadway support systems on gas explosions and found that roadways. The support can promote the development of turbulence and explosion, and can also suppress the propagation of flame and shock wave [11]. Under the same conditions, the shock wave of the roadway support system with a larger distance has greater destructive power; Zipf et al. conducts methane-gas bombardment in the pipeline. Explosion experiment, testing shock wave propagation velocity and pressure data meet the Chapman-Jouguet (CJ) theory [12]; C.K Savinkenko et al. using pipeline experiments The attenuation characteristics of shock waves from gas explosions were discussed, and the attenuation coefficients of shock waves at roadway bends and bifurcations were derived, and a preliminary study of shock propagation characteristics was carried out [13]; Casadei et al. developed techniques and algorithms capable of numerical simulation of fluid-solid coupling and transient dynamics in complex 3D geometries, and found that solid deformation can have an effect on reflected overpressure [14]; Inaba et al. conducted gas explosion experiments in a semi-enclosed space and studied the propagation law of the shock wave [15]. Many experts and scholars on the attenuation
law of the overpressure shock wave, influencing factors, etc., but has not been proposed according to the shock wave to invert the explosion source location and intensity.

In this paper, Fluent software was used to study the law of gas explosion in different sizes of roadway, the maximum overpressure data were subsequently collected, and GA-BP neural network was used to build a roadway gas explosion disaster inversion model, inversion of the gas explosion source location and intensity, to provide theoretical support for the prevention and control of gas explosions in mines and roadway gas explosions and post-disaster emergency relief.

1 GA-BP neural network

1.1 Back propagation neural network theory

Artificial neural networks are inspired by the brain neuron system in living organisms, through which organisms think and generate consciousness and actions, while artificial neural networks are mathematical models that use network topology in the form of a large number of computational units to simulate the way living organisms think and get the expected results through distributed delivery \[^{[16]}\]. Artificial neural networks have advantages over human brain systems in the following aspects: information storage capacity, information memory capacity, fault tolerance, information nonlinear mapping capacity, parallel computing capacity, information association capacity and information input methods, etc. Therefore BP neural network theory is heavily applied to deal with nonlinear complex problems such as the gas explosion problem in this paper. The specific principle is shown in Fig.1 \[^{[17]}\].

![Fig.1 The schematic diagram of BP neural network \[^{[17]}\]](image)

1.2 Genetic Algorithm theory

Genetic Algorithm is a stochastic search optimization algorithm based on natural selection and natural genetic theory, in which new solutions are generated from an initial set of solutions through random optimization processes such as selection, crossover and variation.
1.3 GA-BP Neural Network Principles

The initial weights and thresholds have a great influence on the performance of BP neural network, so GA improves the prediction accuracy of BP neural network by optimizing the initial weights and thresholds, as shown in Fig.2.

![Fig.2 The principle of GA improved BP neural network initial weight and threshold](image)

From Fig.2, the GA adaptation function is correlated with the prediction error function of the BP neural network, and the smaller the error, the higher the individual adaptation in the population. The weights and thresholds obtained through a large number of iterations make the simulation results of the BP neural network using training samples closer and closer to the real results, and when the number of iterations or error accuracy reaches the requirements, the best weights and thresholds are output, and finally the best weights and thresholds are assigned to the BP neural network to greatly increase its prediction performance.

2 Methodology

2.1 Theoretical basis

According to the principle of BP neural network, it is known that training samples are needed to complete the network training, and test samples are needed to test the performance of the network. The sample includes input data and output data, and output data is simulated by input data through the network, after which the error between the real output data and the simulated output data is used to gradually improve the network, and finally a mature model is built after many iterations, so the higher the connection between the input data and output data, the more powerful the model inversion is.
After research shows that the different sizes of roadway gas explosion and the explosive strength of the explosive source location and explosion at various points after the maximum overpressure, marked gas concentration and temperature parameters have a certain non-linear relationship, so this section will be through the roadway cross-sectional area, the maximum overpressure data at different locations inversion of the roadway gas explosion source location and strength, so we need to collect these data, where the explosive strength can be derived from the formula (1).

\[ E = L \cdot S \cdot \varphi_{CH_4} \]  

(1)

In the formula, \( E \) indicates the explosive intensity (MJ); \( L \) indicates the gathering length of combustible gas (m); \( S \) indicates the cross-sectional area of the roadway (m²); \( \varphi_{CH_4} \) indicates the volumetric energy density of methane (MJ/m³), which can be derived from formula (2).

\[ \varphi_{CH_4} = Q_{CH_4} \cdot \varphi_{CH_4} \cdot \rho_{CH_4} \]  

(2)

In the formula, \( Q_{CH_4} \) indicates the heat released by the complete combustion of 1kg methane is 55 MJ \([18]\); \( \varphi_{CH_4} \) indicates the mixed gas concentration, \( \rho_{CH_4} \) indicates the mixed gas density, when \( \varphi_{CH_4} = 9.5\% \), \( \rho_{CH_4} = 0.068 \text{ kg/m}^3 \).

### 2.2 Modeling basis

The experiment were established to establish an effective area of 3.6 m², but the length and width of 0.2 m×18 m, 0.3 m×12 m and 0.4 m×9 m two-dimensional straight roadway model, and numbered for the model 1, model 2 and model 3, in order to ignore the shock wave to reach the right vertex when the rebound to the impact of the explosion, the model are the left end of the closed end, the right end for the exit end, and ignition source located in the left side of the model port on the central axis. In addition, in order to effectively study the gas explosion size effect, we need to ensure that the energy produced by each gas explosion is the same, so we determine the premixed gas (methane-air mixture) area for the gas explosion to be 1.8 m², the rest of the area for the general atmosphere, through the calculation, we can see that the model 1 premixed gas length is 9 m, model 2 premixed gas length is 6 m, model 3 premixed gas length is 4.5 m, the specific model is shown in Fig.3.

![Model Schematic](image)

**Fig.3** The schematic of model

It can be known from Fig.3 that the roadway axis was set up on the 12 monitoring points, each model monitoring point layout details is shown in Table 1. By observing and analyzing the changes of each parameter, the propagation law of gas explosion process of different sizes is
studied.

| Number | Effective Area/m² | Distance from ignition end/m | Proximity of monitoring points/m |
|--------|-------------------|------------------------------|---------------------------------|
|        | Model 1 | Model 2 | Model 3 | Model 1 | Model 2 | Model 3 |
| 1      | 0.704   | 3.52    | 2.35    | 1.76    | 0.00    | 0.00    |
| 2      | 1.304   | 6.52    | 4.35    | 3.26    | 3.00    | 2.00    | 1.50    |
| 3      | 1.688   | 8.44    | 5.63    | 4.22    | 1.92    | 1.28    | 0.96    |
| 4      | 1.840   | 9.20    | 6.13    | 4.60    | 0.76    | 0.5     | 0.38    |
| 5      | 1.946   | 9.73    | 6.49    | 4.87    | 0.53    | 0.36    | 0.27    |
| 6      | 2.116   | 10.58   | 7.05    | 5.29    | 0.85    | 0.56    | 0.42    |
| 7      | 2.224   | 11.12   | 7.41    | 5.56    | 0.53    | 0.36    | 0.27    |
| 8      | 2.476   | 12.38   | 8.25    | 6.19    | 1.26    | 0.84    | 0.63    |
| 9      | 2.670   | 13.35   | 8.90    | 6.68    | 0.97    | 0.65    | 0.49    |
| 10     | 2.862   | 14.31   | 9.54    | 7.16    | 0.96    | 0.64    | 0.48    |
| 11     | 3.076   | 15.38   | 10.25   | 7.69    | 1.06    | 0.71    | 0.53    |
| 12     | 3.420   | 17.10   | 11.40   | 8.55    | 1.72    | 1.15    | 0.86    |

2.3 Data base

The data will use FLUENT simulation of straight roadway gas explosion data to establish a BP neural network, in order to ensure that the sample is sufficient, we need to change the initial conditions (location of the explosion source and gas - air mixed volume) to get more data under different conditions, the specific simulation of the initial conditions is shown in Table 2, the table does not appear in the initial conditions of its settings and the same initial conditions mentioned in Table 1.

Simulation is performed according to the initial conditions in Table 2 to obtain the maximum overpressure data for different monitoring locations, as shown in Fig.5. In order to ensure the diversity and versatility of network training samples, it is necessary to collect more explosion data of tunnel gas under different working conditions. According to the literature, the United States Bureau of Mines [20], the maximum overpressure data of the tunnel gas explosion experiment conducted by China Mining, and the maximum overpressure data and maximum overpressure data of the pipeline gas explosion experiment conducted by the University (Beijing). China University of Mining and Technology (Beijing) used Simtec software to simulate the tunnel gas explosion [19]. The specific data is shown in Fig.4 to Fig.9.
Table 2 The initial conditions of gas explosion in FLUENT simulation roadway under different working cases

| Roadway length/m | 18 | 18 | 18 | 18 | 12 | 12 | 12 | 9 | 9 | 9 | 9 |
|------------------|----|----|----|----|----|----|----|---|---|---|---|
| Roadway cross section/m² | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 |
| Combustible gas volume/m³ | 1.8 | 1.8 | 1.2 | 2.4 | 1.8 | 1.8 | 2.7 | 1.8 | 1.2 | 2.4 |
| Explosion source location/m | 0 | 1 | 3 | 5 | 0 | 1 | 3 | 5 | 0 | 1 | 3 | 5 |
| Explosion source intensity/Mpa | 0.64 | 0.64 | 0.43 | 0.85 | 0.64 | 0.64 | 0.43 | 0.96 | 0.64 | 0.64 | 0.43 | 0.85 |

Fig. 4 The maximum overpressure data of gas explosion in FLUENT simulation roadway under different working conditions

Fig. 4 shows the maximum overpressure data and the explosive source strength for the 12 conditions simulated using Fluent. Fig. 4(a) indicates that in each condition, the maximum overpressure data for each coordinate; Fig. 4(b) indicates the strength of the explosive source of each condition. It is can be found in Fig.4, the roadway gas explosion to change the explosive source location, the maximum explosive overpressure will also change accordingly, the closer the explosive source location of the opening, the same location of the maximum overpressure produced by the smaller. For instance in Fig.4, the explosive strength is 0.64 MJ, in the same monitoring location under different sizes of roadway explosive source 1m explosion at the source of the maximum overpressure is generally greater than the explosive source for 0 m at the maximum overpressure produced; the same change in gas explosive strength will also have an impact on the maximum explosion overpressure, the higher the intensity of the gas explosion, the greater the maximum overpressure generated by the same location, such as the explosive source for 5 m, the explosive strength of 0.85/0.96 MJ, when the maximum explosive overpressure is generally greater than the explosive source for 3m, the explosive strength of 0.4 3MJ; changing the location and intensity of the explosion source has no effect on the maximum overpressure change.
law of different monitoring points under the same working condition, and generally shows that the closer the monitoring point is to the opening position, the smaller the maximum overpressure.

Fig.5 The maximum overpressure data of the gas explosion experiment in roadway of the China University of Mining and Technology (Beijing) [19]

Fig.5 above shows the maximum overpressure data from the roadway gas explosion experiment conducted by China University of Mining and Technology (Beijing). Fig.5(a) shows the case of eight coordinates in the roadway and the different maximum overpressure data corresponding to each coordinate; Fig.5(b) shows the intensity and location of the explosion source in nine different conditions.

Fig.6 The maximum overpressure data of gas explosion in Simtec simulation roadway from China University of Mining and Technology (Beijing) [18]

Fig.6 above shows the maximum overpressure data from a simulated roadway gas explosion using Simtec software at China University of Mining and Technology (Beijing). Fig.6(a) shows the case of eight coordinates on the roadway and the different maximum overpressure data corresponding to each coordinate; Fig.6(b) shows the strength and location of the explosive source in 12 different conditions.
Fig.7 The maximum overpressure data of gas explosion experiment in roadway of the U.S. Mining Bureau [20]

Fig.7 above shows the maximum overpressure data from the roadway gas explosion experiment conducted by the United States Bureau of Mines. Fig.7(a) shows the eight coordinates of the roadway and the different maximum overpressure data corresponding to each coordinate under five conditions; Fig.7(b) shows the strength of the explosive source under five different conditions when the location of the explosive source is the starting point on the left side of the roadway (0.00 m).

Through the observation of Fig.5 to Fig.7 found that the relationship between the maximum overpressure and detonation source location and strength of the above Fig.5 shows the law is basically the same, which indirectly proves the validity of the Fluent simulation data. In addition, Hu et al. proposed that in the cross-section of 0.2 m×0.2 m, 18 m long closed pipe filled with half the volume of the concentration of 9.5% of the gas, after ignition at 0m to get the maximum overpressure of 162.13 kPa [21]. This experiment in the model cross-sectional area of 0.2 m×1 m, the rest of the same conditions using Fluent simulation (Fig.5 in the case of the condition 1), the maximum overpressure obtained is 154.89 kPa, which is slightly inaccurate due to the increase in tunnel volume and the effect of the exit at the right end of the model, but within acceptable limits, which further demonstrates the validity of the Fluent simulation data.

3 Application of disaster inversion model for roadway gas explosion

This time, GA improved BP neural network will be used to establish a roadway gas explosion disaster inversion model, and the location and intensity of the explosion source will be inverted using 8 sets of locations and maximum overpressure data of gas explosions in roadways of different sizes. According to the above, there are 38 sets of data. We will use 29 sets of data as training samples and 9 sets of data as test samples. The specific data distribution is shown in Table 3. It can be found that the sources of training and test data samples are universal and diverse. This not only increases the inversion capability of the model, but also the inversion results obtained are more scientific.
Table 3 The allocation details of inversion data

| Inversion data classification | Data sources          | Quantity |
|-------------------------------|------------------------|----------|
| Training samples              | FLUENT simulation      | 9        |
|                               | U.S. Bureau of Mines   | 4        |
|                               | CUMTB experiment       | 7        |
|                               | CUMTB simulation       | 9        |
| Test sample                   | FLUENT simulation      | 3        |
|                               | U.S. Bureau of Mines   | 1        |
|                               | CUMTB experiment       | 2        |
|                               | CUMTB simulation       | 3        |
| Input data                    | Roadway cross section  | 1        |
|                               | Coordinate position of measuring point | 8 |
|                               | Maximum overpressure at measuring point | 8 |
| Output data                   | Explosion source position | 1     |
|                               | Explosion source intensity | 1     |

The GA-BP neural network needs to set a large number of parameters and functions, and the values of some of these parameters play a key role in the performance of the inversion model, so it is necessary to carry out more trial and error to select the parameters that make the error of the results smaller, as shown in Table 4.

Table 4 shows that the model implied layer nodes are set to 2 to 35, the population size is set to 15/30/50/70, this is because according to the above that these two parameters have a great impact on the performance of the model. Then MATLAB software is used to realize the preliminary roadway gas explosion disaster inversion model, after the different implied layer node number and population size into the code for 10 times, the statistical output of each time the absolute error of the average of the absolute value of the sum, if the average error is smaller, on behalf of the model performance is better, so as to select the appropriate parameters, specific statistical results are shown in Fig. 8.
Table 4 The parameter and function setting of GA-BP neural network

| Set content                           | Parameter/Function     |
|---------------------------------------|------------------------|
| the number of node of hidden layer    | 2, 3, ..., 35          |
| Node hidden layer transfer function   | Tansig                 |
| Node of output layer transfer function| Purelin                |
| Training function                     | Trainlm                |
| E-learning function                   | Learned                |
| Population size                       | 15/30/50/70            |
| Genetic algebra                       | 1000                   |

![Graph](image1.png)

**Fig.8 The error statistics of inversion results under different hidden layer nodes and population scale**

When all the parameters are true, we use MATLAB software to realize the final roadway gas explosion disaster inversion model, and then 9 groups of test samples are input to get the corresponding inversion results, and compare with the real results, as shown in Figure 9. In order to better analyze the inversion effect, the absolute error and the mean square error between the inversion result and the real result were also calculated, as shown in Fig.10 and Table 5.

![Graph](image2.png)

**Fig.9 The comparison of inversion value and real value**
It can be seen from Fig. 9, Fig. 10 and Table 5 that the model has high accuracy in the inversion of the explosive source position and relatively low accuracy in the inversion of the explosive source intensity. This is due to the large difference in the intensity data of the explosive source of the training samples, resulting in accuracy relatively low. But on the whole, the mean square error of the tunnel gas explosion disaster inversion model is 7.89, and the overall accuracy is high, indicating that the model has practical reference value, can effectively invert the explosion source location and more effectively invert the explosion source intensity.

4 Conclusion

The BP neural network was established based on the FLUENT simulated gas explosion data in a straight roadway, and the maximum overpressure data at different monitoring locations were obtained. In order to ensure the diversity and universality of network training samples, collect more roadway gas explosion data under different working conditions, and analyze and process these data to get the following conclusions:

(1) When a tunnel gas explosion changes the location of the explosion source, the maximum explosion overpressure will also change accordingly. The closer the explosion source location is to the opening, the smaller the maximum overpressure generated at the same location.

(2) Changing the intensity of the gas explosion will also affect the maximum explosion overpressure. The higher the intensity of the gas explosion, the greater the maximum overpressure generated at the same location.

(3) Changing the location and intensity of the explosion source has no effect on the variation of the maximum overpressure at different monitoring points under the same working condition,
and it generally shows that the closer the monitoring point is to the opening, the smaller the maximum overpressure.

According to the GA improved BP neural network to establish the roadway gas explosion disaster inversion model, by comparing the inversion results with the real results of the error and variance, the calculation results show that the overall accuracy of the roadway gas explosion disaster inversion model results are high and reliable. The inversion model can provide a reference for the emergency rescue and accident investigation of gas explosion in coal mine straight roadway. However, for the strength of the explosive source, the mean error variance and absolute error are relatively large, which may lead to a relatively low precision. If a large number of training samples under different working conditions are increased, the accuracy of the inversion model will be further increased.

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