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Mineral

An optimizing selection model in preparation of powdery emulsion explosives

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Abstract: In order to get cheap and excellent PEE (Powdery Emulsion Explosives), the model of optimizing selection on preparation of PEE was established by the Neural Net Theory (NNT). On the basis of some data in the study of PEE, the training, prediction and optimizing selection of the Neural Net (NN) model were finished by compiling procedures. The results indicate that the model is helpful to the preparation of PEE and worthy to extend and apply broadly.

Key words: neural net; powdery emulsion explosives; preparation; optimizing selection

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1 Introduction

PEE is a new powdery commercial explosive, developed by Chinese independently. It holds the excellence of both emulsion explosives and powdery explosives, such as favorable anti-water capability and characteristics of loading and transport easily. It doesn't pollute environment without TNT. Therefore, It is applied in blasting more and more, and has an attractive market foreground. So, it is becoming one of the focuses of researchers trying to find the way to obtain cheap and excellent PEE.

The capabilities of explosives are affected by many factors, such as components and the processes of preparation, that have a complicated internal relationship. As to these complicated and internal relations in system under the action of many factors, it can't be described satisfactorily by normal math methods. NNT provides an effective method to solve this problem. NNT is a new subject developed rapidly in recent years, it is fit especially to solve some complicated uncertain relations in system under the action of many factors.

2 Neural net theory (NNT)

NNT is a highly non-linear dynamics system. Although one nerve cell has simple structures and functions, a net system consisted of many nerve cells have wondrously abundant and complicated behaviors [1]. It has a process of self-adapting and self-studying, finds quantitative relations between the input and output of model according to data of training samples, then it can make prediction of system.

Back-Propagation (BP) net is a feedforward networks with the function of reverse transmit and consisted of non-linear switch cells, it is a NN used mostly. Besides input layer cells and output layer cells, it has hidden layers cells (one layer or multilayer) as well. **Figure 1** is a sketch map of typical BP net.

BP net arithmetic is a self-study arithmetic depending on the basis of grads descending method. See from figure 1, after disposal of hidden cells, information from input layer is transmitted to output layer. The status of each layer only affect the action of next layer [2]. If results from output layer are not satisfied, the error message will transmit reversely along primary route and modify each layer's weights until get satisfied error message.

If there are P input samples, then input vector is X^k ($k=1,2,\cdots,P$) and expected output vector is T^k ($k=1,2,\cdots,P$). The arithmetic of BP net will be described as follow:

(1) Initialize model, give initial values to all weights and thresholds.

(2) Input study samples and calculate the input and

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output of each layer according to the following equations.

$$u_j^k = \sum_i W_{ij} o_i^k - \theta_j \quad (1)$$

$$o_j^k = f(u_j^k) = f(\sum_i W_{ij} o_i^k - \theta_j) \quad (2)$$

where W_{ij} is the weight of node i and node j. θ_j is the threshold of node j. $f(\cdot)$ is the node function, which can be a linear one or S type nonlinear one.

(3) Calculate the model error according to the equation (3). If the model error $E \geqslant e$ or individual error $|t_i^k - y_i^k| \geq e$, then go to the step 4. Otherwise, it means the model results meet the requirements.

$$E = \sum_{k=1}^{p} E_k = \frac{1}{2} \sum_{k=1}^{p} \sum_{i=1}^{n} (t_i^k - y_i^k)^2 \quad (3)$$

(4) Calculate the modified grads errors δ_j^k of each layer according to the equation (4), then modify the weights through equation (5).

$$\frac{\partial E_k}{\partial W_{ij}} = \frac{\partial E_k}{\partial u_j^k} \cdot \frac{\partial u_j^k}{\partial W_{ij}^k} \quad (4)$$

$$W_{ij}^{(c+1)} = W_{ij}^{(c)} + \eta \cdot \frac{\partial E}{\partial W_{ij}} = W_{ij}^{(c)} + \eta \sum \delta_j^k o_i^k \quad (5)$$

where η is the study step pace.

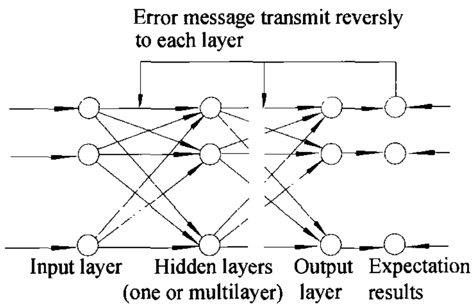

Figure 1 The sketch map of BP net.

3 Establishment of NN model of optimizing selection

3.1 Input nodes

It was well known that the capability and price of PEE are controlled by components and processes of preparation. In order to produce cheap and excellent explosives, not only the components, but also the processes of preparation should be concerned. On this basis, the NN model of optimizing selection on preparation of PEE can be found.

The main components of PEE are ammonium nitrate, water, emulsion, and additives. These components and their contents (mass fraction) are listed in following: ammonium nitrate, 87%-93%; water, 0-8.0%; emulsion, 1.5%-2.5%; compound oil, 3.6%-5.5%; additives, 0.1%-0.5%.

The main processes of preparation of PEE include rate of adding materials, emulsifying temperature, whisking rate and spray pressure, *etc*. They take a great role in the preparation of PEE, and should be concerned in the model. These factors and their value range are listed in following: rate of adding materials, 55-110 g/s; emulsifying temperature, 110-150°C; whisking rate, 10-16 r/s; spray pressure, 0.1-0.5 MPa.

The components and processes of preparation are influencing factors of system. So, these 9 factors are taken as input cells of the model, it means the model has 9 input nodes.

3.2 Output nodes

The optimizing selection of explosive should concern its capability and cost, so the ratio of detonation capability and cost should be taken as an index to evaluate PEE. There are many factors which can be used to describe the capability of PEE. In this paper, detonation velocity is selected to describe it. Therefore, the ratio of detonation velocity and cost are output cell. In a word, the model has one output node.

3.3 Hidden nodes

Rebert thought that a BP net with one hidden layer can describe any mapping of $n \times m$ dimensions [4]. So a BP net with one hidden layer are selected to found the model.

There are no theoretical formulas be used to calculate the number of hidden cells, while it is selected by the experiential equation:

$$n = \sqrt{m+k} + a \quad (6)$$

where n is the number of hidden cells, m and k are the number of input cells and output cells respectively, while a is a constant between 1 and 10.

According to experience, the more hidden nodes, the better prediction effect of networks. The number of hidden nodes should be no less than the sum of number of input and output nodes. According to the equation (6), the number of hidden nodes is designated as 12.

The structure of BP model is constructed 3 layers, including 9 input nodes, one output node and 12 hidden nodes. These input nodes delegate ammonium nitrate, water, emulsion, compound oil, additives, rate of adding materials, emulsifying temperature, whisking rate and spray pressure. Output nodes delegate the ratio of detonation velocity and cost.

Obviously, the weights of the input layer and hidden layer formed a matrix of 9×12 ranks, the weights of hidden layer and output layer formed a vector with 12 elements.

4 Application of optimizing selection model

4.1 Model training

As the structure of optimizing selection model is determined, the model can be trained according to the structure and arithmetic of the model as long as training samples are selected. More training samples will result in higher precision of the model. 20 samples are selected from the data accumulated in the study of PEE. The data of samples are listed in **table 1**.

Table 1 The training data of model

Serial number	Components and their mass fraction/ %					Processes of preparation				The ratio of capability and cost/ m·kg·(¥·s)$^{-1}$
	Nitrate	Water	Emulsion	Compound oil	Additives	Rate of adding materials/ g·s^{-1}	Emulsify temperature /°C	Whisking rates / r·s^{-1}	Spray pressure/ MPa	
1	87	6.5	1.8	4.5	0.2	110	130	10	0.2	2150.7
2	88	6.0	1.7	4.0	0.3	80	130	13	0.4	2179.5
3	89	2.9	2.6	5.0	0.5	110	120	10	0.4	1992.7
4	93	1.5	1.6	3.7	0.2	110	140	10	0.3	1974.3
5	89	4.3	1.9	4.5	0.3	80	140	13	0.3	1509.4
6	88	4.4	2.0	5.4	0.2	80	140	13	0.2	1541.9
7	88	4.8	2.3	4.5	0.4	55	140	13	0.3	1353.0
8	90	3.3	2.5	4.0	0.2	110	120	10	0.5	2102.7
9	93	1.7	1.5	3.6	0.2	80	130	10	0.2	2350.8
10	88	4.8	1.8	5.0	0.4	80	140	10	0.5	1377.5
11	89	4.5	2.2	3.8	0.5	110	120	13	0.1	1909.1
12	89	4.5	1.6	4.8	0.1	110	140	13	0.2	1772.0
13	89	5.0	1.8	3.9	0.3	110	140	10	0.2	2271.2
14	89	3.6	2.2	5.0	0.2	80	140	13	0.2	1307.3
15	92	2.4	1.6	3.8	0.2	110	120	13	0.2	2006.2
16	87	5.1	2.3	5.1	0.5	80	120	13	0.2	2453.6
17	88	6.3	1.7	3.6	0.4	80	140	13	0.2	2051.4
18	92	2.6	1.5	3.8	0.1	55	120	16	0.2	1444.6
19	90	4.7	1.5	3.6	0.2	110	140	16	0.1	2227.5
20	91	3.1	1.8	3.8	0.3	110	140	13	0.3	2171.4

Procedures are compiled to do the model's training, prediction and optimizing selection, according to BP net arithmetics. The output node function is linear and hidden node function is S type nonlinear.

The training precision of the model is 0.001, as study step pace is 0.05. After thousands iterations, the precision meet the requirement and the training terminates. Up to now, the weights of the model are all determined.

4.2 The prediction and optimizing selection of model

In order to select optimizing components and processes, values for 9 factors of the model are got by computer according to their value ranges. Computer will pick values automatically through different paces. These data are samples to be used in prediction. Input the samples picked by computer automatically to the model, the ratio of capability and cost of them can be obtained.

Table 2 lists some results of the model prediction, as the data are obtained from predicted results by computer.

The optimizing selection of model is finished by computer automatically. It chooses the biggest ratio of capability and cost among all the predictions of samples. As a result, the sample with the biggest ratio is the best components and processes. After optimizing, the best components and processes are listed in following, (1) components and their contents: nitrate, 91%; water, 3.0%; emulsion, 1.7%; compound oil, 4.0%; additives, 0.2%; (2) processes of preparation: rate of adding materials, 110 g/s; emulsifying temperatur, 130°C; whisking rate, 10 r/s; spray pressure, 0.2 MPa; (3) the ratio of capability and cost, 2841.3m/s·kg.

Table 2 Some predicted results of model

Serial number	Components and their contents / %					Processes of preparation				The ratio of capability and cost / m·kg·(¥·s)$^{-1}$
	Nitrate	Water	Emulsion	Compound oil	Additives	Rate of adding materials/g·s^{-1}	Emulsifying temperature/°C	Whisking rate/ r·s^{-1}	Spray pressure/ MPa	
1	90	4.3	2.0	3.5	0.2	80	140	10	0.3	2443.4
2	90	3.4	2.2	4.0	0.4	80	130	13	0.1	1948.4
3	89	5.1	1.9	3.8	0.2	80	140	13	0.4	2086.2
4	92	2.4	1.8	3.6	0.2	110	110	16	0.4	2152.7
5	93	1.9	1.5	3.5	0.1	110	130	13	0.1	1946.7
6	89	3.8	2.3	4.5	0.4	110	120	10	0.1	1622.8
7	90	3.7	2.2	3.8	0.3	80	130	10	0.2	2124.2
8	91	2.1	2.1	4.6	0.2	110	130	13	0.1	1514.4
9	90	3.6	2.0	3.9	0.5	80	140	13	0.3	2091.1
10	87	6.4	1.8	4.3	0.5	110	150	13	0.4	1256.7
11	93	1.4	1.7	3.5	0.4	80	120	13	0.4	2563.8
12	91	2.8	1.5	4.4	0.3	80	120	16	0.2	1930.8
13	91	3.0	1.6	4.0	0.3	80	120	10	0.2	2731.4
14	91	3.7	1.6	3.5	0.2	110	120	13	0.2	1905.4
15	92	2.1	1.7	4.0	0.2	80	130	16	0.3	1902.8
16	90	3.7	1.8	4.2	0.3	80	120	13	0.3	2369.2
17	87	7.0	2.0	3.8	0.2	80	120	10	0.4	2791.0
18	93	1.4	1.9	3.5	0.2	80	110	13	0.1	2042.3
19	90	3.3	1.9	4.5	0.3	80	120	16	0.1	1975.0
20	91	3.5	1.5	3.6	0.4	110	120	16	0.3	2278.9

5 Conclusions

After application of the model, compared the predicted results with the test results, it can be concluded that:

(1) After test and calculation, the test value of the ratio of capability and cost is 2767.4 m·kg·(¥·s)$^{-1}$. Compared with the prediction, its relative error is 2.7%. It means that the model has a higher precision and it is worthy to reference in the study of PEE.

(2) As to explosives with same components, best processes of preparation can be obtained. The experiments of PEE indicate that the method to determine the best processes of explosives with different components by the model is quite reliable.

(3) The model takes advantage of computer to pick values of input nodes automatically within their value range, as it has many input nodes and the amount of samples obtained by computer is very large. The computing capacity is also increased. But at a certain degree, it indicate that the model is comprehensive for choosing samples. It ensured the reliability of the model.

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