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Forecasting the yield of oil field gas with the fuzzycomprehensive evaluation method and the genetic algorithm

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ABSTRACT

The fuzzy comprehensive evaluation method and the genetic algorithm for predicting the yield of oil field gas have been introduced in the present article. Two new methods for forecasting the yield of oil field gas in China have also pointed out based on the fuzzy comprehensive evaluation method and the genetic algorithm. The experimental results show that both models can predict the yield of oil field gas in China and the experimental data are in agreement with the quantitatively analytical conclusions drawn from the calculated data. This proves that two types of new models can be used to predict the yield of oil field gas. It results in good economic and social benefits in China.

KEYWORDS

Forecast;
Oil field gas;
China;
Fuzzy comprehensive evaluation method;
Genetic algorithm.

INTRODUCTION

Oil field gas (natural gas) has a lot of advantages such as clean, highly efficient, abundant and easily stored. The global oil field gas yield and consumption in 2005 reached 2.763×10^{12} m^3 and 2.749×10^{12} m^3, respectively. The demand for oil field gas had gradually increased to 3.3% of the global oil field gas yield every year and was 25% of total energy. Chinese oil field gas consumption was only 1.7% of total world natural gas consumption; however Chinese increment in oil field gas consumption got 20.8%. Oil field gas as a clean energy is widely used in different areas such as electricity power, car market and residential fuel, etc[1].

In the present paper, the fuzzy comprehensive evaluation method and the genetic algorithm have been discussed. Two new methods for forecasting oil field gas yield in China have also explained based on the fuzzy comprehensive evaluation method and the genetic algorithm.

RESULTS AND DISCUSSION

The fuzzy comprehensive evaluation method[2]

It was supposed that an actual value was $y(t)$ at the time (t) by using m types of forecasting methods. Its forecasting value was $y_i(t)$ when i type of forecasting method was used. Furthermore, its forecasting absolute error value was written as follows.

$$e_i(t) = y(t) - y_i(t)$$

Where $i = 1, 2, L, m$ and $t = 1, 2, L, m$

It was supposed that weight average (W) for forecasting model was described as follows.

$$W = (w_1(t), w_2(t), L, w_m(t))$$

Where $\sum_{i=1}^{m} w_i(t) = 1$.

The final forecasting model was listed as follows.

$$\hat{y}(t)=\sum_{i=1}^{m} w_i(t)\times y_i(t)$$

The absolute error value ($e_i(t)$) and the relative error value ($\eta(t)$) were written as follows.

$$e_i(t)=y(t)-\hat{y}_i(t)$$

$$\eta(t)=\frac{e(t)}{y(t)}\times 100\%$$

It is very important to set up the membership function during checking the fuzzy comprehensive evaluation method. Wang Hongming introduced the principle of the fuzzy comprehensive evaluation method and the language constant. He also explained the concept about fuzzy sets which included $S_{excellent}$, S_{good} and S_{bad} . Their functions were written as follows.

$$\mu_{S_{excellent}}(x)=e^{\frac{(x-0.15)^2}{2\times 0.0106^2}}$$

$$\mu_{S_{good}}(x)=e^{\frac{(x-0.5)^2}{2\times 0.0106^2}}$$

$$\mu_{S_{bad}}(x)=e^{\frac{(x-0.85)^2}{2\times 0.0106^2}}$$

Where μ- the membership function $x\subset X$ - the language function

The fuzzy comprehensive evaluation method was one type of the basic application method. It was totally evaluated based on the fuzzy set transformation principle and the theory of membership degree. It was supposed that a factor set (U) and a comment set (V) were written as follows, respectively.

$$U=\{u_1,u_2,u_3,L,u_m\}$$

$$V=\{v_1,v_2,v_3,L,v_n\}$$

R was a fuzzy relation from the factor set (U) to the comment set (V). The fuzzy relation (R) was described as follows.

$$R=\begin{pmatrix} R_1\\ R_2\\ M\\ R_m\end{pmatrix}=\begin{pmatrix} r_{11} & r_{12} & L & r_{1n}\\ r_{21} & r_{22} & L & r_{2n}\\ M & M & & M\\ r_{m1} & r_{m2} & L & r_{mn}\end{pmatrix}$$

Where $r_{ij}=\mu_R(u_i,u_j),0\le r_{ij}\le 1$.

Different factors had a different effect on an affair, so ratio of a factor to the whole affair must be considered. A fuzzy vector (A) was written as follows.

$$A=(a_1,a_2,L,a_m)$$

Where - having an effect on the single factor u_i.

When the fuzzy vector (A) and the fuzzy relation (R) was solved, the comprehensive evaluation vector (B) was described as follows.

$$B=A\square\ R=(b_1,b_2,L,b_n)$$

Where was evaluated based on the single factor .

There are three methods to solve b_j, such as $M(\wedge,\vee)$, $M(\bullet,\oplus)$ and $M(*,\wedge)$. Results got from three methods were B_1, B_2 and B_3, respectively. It was supposed that a compound vector (B^*) was written as follows.

$$B^*=(B_1,B_2,B_3)$$

It was supposed that the weight average (λ) of three methods was listed as follows.

$$\lambda=(\lambda_1,\lambda_2,\lambda_3)$$

Where $\lambda_i\ge 0$ and $\sum_{i=1}^{5}\lambda_i=1$.

Comprehensive evaluation vector (P) at the second time was evaluated as follows.

$$P=\lambda\square\ B=(p_1,p_2,L,p_n)$$

It was supposed that advantages of the fuzzy set S_i for the fuzzy set S_j was $q_\delta(S_i,S_j)$.

$$q_\delta(S_i,S_j)=v(\mu\le s_i(x)\wedge\mu\le s_j(x))\times\max\frac{\mu_{s_i(x)}}{\mu_{s_j(x)}}$$

Where $x\subset X$

$$\mu\le s_i(x)=\max(\mu_{s_i(x)})\qquad x<x^*$$

$$\mu\le s_i(x)=\mu_{s_i(x)}\qquad x\ge x^*$$

x^*- x of $\max(\mu_{s_i(x)})$.

The optimum fuzzy set () was described as follows.

$$Q_\delta=\begin{pmatrix} q_\delta(1,1) & q_\delta(2,1) & L & q_\delta(1,k)\\ q_\delta(2,1) & q_\delta(2,2) & L & q_\delta(2,k)\\ M & M & & M\\ q_\delta(k,1) & q_\delta(k,1) & L & q_\delta(k,k)\end{pmatrix}$$

The fuzzy vector W was written as follows.

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$W = (w_1(t), w_2(t), L, w_k(t))$

Where $w_i(t) \bigwedge_{j=1}^{k} q_\delta(i,j)$

The final weight average (w) was listed as follows.

$$W = \left[\frac{w_1(t)}{\sum_{i=1}^{n} w_i(t)}, \frac{w_2(t)}{\sum_{i=1}^{n} w_i(t)}, L, \frac{w_n(t)}{\sum_{i=1}^{n} w_i(t)} \right]$$

TABLE 1 showed the relationship between different prediction models and predicting the yield of oil field gas for small pieces of oilfield. Experimental results presented that the yield of oil field gas calculated by the fuzzy comprehensive evaluation method was close to the actual value.

TABLE 1 : The relationship between different prediction models and predicting the yield of oil field gas for small pieces of oilfield.

Different prediction models	Yields of oil field gas (m^3)
Declining model	16.12
Water drive characteristic model	16.32
Logic model	18.51
Differential Model	17.24
Neuralnetworkmodel	17.21
fuzzy comprehensive evaluation model	17.35
Actual value	17.30

The genetic algorithm for forecasting the yield of oil field gas[3].

The generalized Wengshi model was a model for predicting oil field gas production[4]. Chen Yuanqian explained more details about the generalized Wengshi model. Its model was written as follows.

$$Q = at^b e^{-\frac{t}{c}}, t = y - y_0$$

Where a - constant; $a > 0$; b - constant; c - constant; y - the prediction of the year; y_0 - the beginning of the year.

Yang Shuzi[5] introduced an exponential smoothing model which could forecast oil field gas production. The exponential smoothing model meant that a predicted value at the time (t+1) weighted average with an experimental value. The exponential smoothing model was listed as follows.

$$\bar{x}_{t+1} = a_0 x_t + (1 - a_0)\bar{x}_t, 0 \le a_0 \le 1.$$

When a_0 equals 1, $\bar{x}_{t+1} = x_t$. It means the predicted value equals the experimental value at the time (t). When a_0 equals 0, the predicted value does not change.

ShuaiXunbo pointed out the optimum group model about predicting the yield of oil field gas. The optimum group model meant that the generalized Wengshi model connected with the exponential smoothing model together. It was written as follows.

$$Q = \beta a t^b e^{-\frac{t}{c}} + (1-\beta)[a_0 x_t + (1-a_0)\bar{x}_t]; 0 \le a_0 \le 1; 0 \le \beta \le 1$$

Where a_0 - constant; β - weight average; Q - the optimum group model.

The optimum group model was calculated based on the genetic algorithm. There were four steps described as follows. (1) It made sure population size (s), crossover probability (p_c),mutationprobability (p_m) and iteration condition. N types of beginning populations were determined. (2) Each fitness function value was computed. (3) Its reproduction probability was calculated based on the above fitness function value. It was supposed that crossover probability (p_c) andmutationprobability (p_m) were known during the genetic process. Finally N types of new populations were gotten. (4) Steps (2) and (3) did not redo until its result was convergence. The final optimum group model was listed as follows.

$$Q_{Calculation}(a,b,c,a_0,\beta) = \beta a t^b e^{-\frac{t}{c}} + (1-\beta)[a_0 x_t + (1-a_0)\bar{x}_t];$$
$$a>0; b\ge 0; c>0; 0\le a_0 \le 1; 0 \le \beta \le 1$$

Small pieces of oil field gas in Liaohe oilfield were forecasted. It was supposed that population size (s), crossover probability (p_c),mutationprobability (p_m) and iteration number were 80, 0.60, 0.001 and 1600, respectively. Parameters of the optimum group model were listed in TABLE 2. Using above parameters forecasted the yield of oil field gas shown in TABLE 3. Experimental results showed that relative errors of the optimum group model were lower than these of the generalized Wengshi model, so the optimum group model was better than the generalized Wengshi model.

TABLE 2 : Parameters of the optimum group model

Parameter	a	b	c	a_0	β
Optimum value	82.60569	0.65824	7.39091	1.26201	0.24167

TABLE 3 : Comparison between the optimum group model and the generalized wengshi model

Yields	The generalized Wengshi model		The optimum group model	
	Forecasting yields (10^4m^3)	Relative errors (%)	Forecasting yields (10^4m^3)	Relative errors (%)
99.60	81.55	18.12	93.01	6.62
149.91	120.34	19.73	141.89	5.35
193.23	160.97	16.70	180.73	6.47
205.20	197.26	3.87	210.25	2.46
255.64	250.46	2.03	255.31	0.13
304.83	280.54	7.97	300.08	1.56
333.62	352.73	5.73	347.82	4.26
231.65	310.57	34.07	288.92	24.72
163.28	260.31	59.43	205.36	25.77
141.63	200.72	41.72	138.26	2.38

CONCLUSION

In this paper, the author has introduced that the fuzzy comprehensive evaluation method and the genetic algorithm lead to and are closely in accordance with predicting the practical experimental values. Oil field gas yield in China can be accurately estimated. Thefuzzy comprehensive evaluation method and the genetic algorithm point out that predicting oil field gas yield not only has a very important significance, but also provides a theoretical reference for chemical plants or oil companies. It is important for Chinese government to design and utilize rightly and optimize natural resources and may increase Chinese government's benefits. This mathematical method is effective, economic, simple and convenient and thus it is suitable for chemical plants or oil companies in China.

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