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一种基于指数平滑的天然气产量灰色预测模型

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摘 要:常规灰色预测模型所需样本数据量较少,容易对预测有用的信息量隐含丢失,在天然气产量预测应用中存在着预测精度不高的问题。应用指数平滑法对天然气产量样本数据进行处理,既充分利用样本中的有用信息,又减少其随机性;然后再对灰色模型的背景值计算方法进行了改进,将样本数据变换成规律性强的呈指数变化的序列,从而提出了一种基于指数平滑改进的天然气产量灰色预测模型。实例分析表明,该模型比常规灰色预测模型有更高的预测精度。

关键词:指数平滑;灰色模型;天然气;产量预测

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One Natural Gas Production Prediction Grey Model Based on Exponential Smoothing

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Abstract: In order to improve forecasting ability of grey model in prediction of natural gas production, one improved grey model is put forward in this paper, which is based on exponential smoothing method and improved calculating method of background value. Exponential smoothing method is used firstly not only makes full use of the available information but also diminishes the randomness of data. Then the calculating method of background value of grey model is improved to transform the calculated production data to be a regular exponential variety sequential. Experiments show the improved grey model has more reliable forecasting ability.

Key words: exponential smoothing method; grey model; natural gas; production predict

1 Introduction

More precise prediction of natural gas production is important for the scientific exploitation plan made out and implemented. Grey theory suggested that development disciplinarian of thing could be described faintly through grey prediction model with incomplete information[1], which could describe a system development direction in certain time in case of small sample data, so some prediction methods for natural gas or oil production based on grey model has been proposed[2~6]. Meanwhile its application examples results show there is imprecise prediction problem for the grey model because small sample data can not give complete prediction information. Based on grey model theory combines with the exponential smoothing method, improved combination grey model is put forward in this paper to solve the imprecise problem. Firstly, exponential smoothing method is used to optimize sample data, which not only makes the most of the information of sample data but also reduces its random. Then the calculation of grey model background value is improved, and original surveying data can be transformed to sequence of regular exponential variety. The combination grey model has more precise prediction of natural gas production is proved by experiments.

2 GM(1,1) Method

GM(1,1) is one of the basic model in the theory of grey prediction , in which Accumulated Generating Operation (AGO) is very important data processing method. Random sequence of nonnegative can be transformed to increasing sequence through the AGO to reduce random and seek to change trend of the sample data. GM(1,1)

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modeling method as follows:

Given original sample sequence: $X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\}$. It can be transformed to new sequence: $X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\}$ by using formula (1), which is

$$x^{(1)}(t) = \sum_{i=1}^{t} x^{(0)}(i), (i = 1,2,\cdots,n) \quad (1)$$

Background value is calculated:

$$z^{(1)}(t) = \theta x^{(1)}(t) + (1-\theta)x^{(1)}(t+1), (t = 1, 2, \cdots, n-1) \quad (2)$$

The θ parameter of formula (2) is considered coefficients, and $0 < \theta < 1$.

Grey differential equation:

$$x^{(0)}(t) + az^{(1)}(t) = b \quad (3)$$

Differential equation:

$$\frac{dx^{(1)}}{dt} + ax^{(1)} = b \quad (4)$$

Let be $\boldsymbol{A} = (a, b)^{\mathrm{T}}$

$$\boldsymbol{B} = \begin{bmatrix} -z^{(1)}(2) & -z^{(1)}(3) & \cdots & -z^{(1)}(n) \\ 1 & 1 & \cdots & 1 \end{bmatrix}^{\mathrm{T}}$$

$$\boldsymbol{Y} = [x^{(0)}(2)\ x^{(0)}(2) \cdots x^{(0)}(2)]^{\mathrm{T}} \quad (5)$$

From least square principle, the least - squares solution of formula (4) is

$$\boldsymbol{A} = (\boldsymbol{B}\boldsymbol{B}^{\mathrm{T}})^{-1}\boldsymbol{B}\,\boldsymbol{Y} \quad (6)$$

The grey prediction model of $X^{(1)}$is established through the two parameters of a and b are figured out:

$$\hat{X}^{(1)}(t+1) = (x^{(0)}(1) - \frac{b}{a})e^{(-at)} + \frac{b}{a}, (t = 1, 2, \cdots, n-1) \quad (7)$$

The grey prediction model of $X^{(0)}$ is established accordingly:

$$\hat{X}^{(0)}(t) = \hat{X}^{(1)}(t) - \hat{X}^{(1)}(t-1) = (1 - e^{a})(x^{(0)}(1) - \frac{b}{a})e^{(-at)}, (t = 1,2,\cdots,n-1) \quad (8)$$

3 Grey Model Improved Based on Exponential Smoothing Method

3.1 Exponential Smoothing Method

Research shows that the mathematical expectation of natural gas production data varies with time in certain period because of a series of unpredictable factor such as exploitation technology progress, which has significant time series feature.

Linear Exponential Smoothing Model:

$$S(t) = k\varphi(t) + (1-k)S(t-1); (0 \leqslant k \leqslant 1) \quad (9)$$

$S(t)$ is prediction value, $\varphi(t)$is sample data, and k is smoothness index determines prediction accuracy of formula (9). The value of k is 0.05 to 0.45 when sample data shows irregular change but presents gentle trend, otherwise the value of k is 0.55 to 0.9 when sample data presents larger fluctuation.

Exponential smoothing method is used not only makes the most of the information of sample data but also reduces its random, so that sample data optimized by exponential smoothing method is propitious to grey model application.

3.2 Improved Grey Model

The calculating method of background value of grey model is key factor effects prediction accuracy, which is revealed by both Tan Guanjun and Zhang Yi[7~9]. Then the calculating method of grey model background value is improved in this paper from this point of view, the realization steps of calculating method of GM(1,1) background value as follows:

Step 1: $z^{(1)}(t) = \theta x^{(1)}(t) + (1-\theta)x^{(1)}(t+1)$, $(t = 1,2,\cdots,n-1)$, the background value sequence of $X^{(1)}: z^{(1)} = \{z^{(1)}(1), z^{(1)}(2), \cdots, z^{(1)}(n)\}$; θ is 0.5 for the first calculation.

Step 2: The parameter a and parameter b of grey differential equation are figured out according to the formula (6).

Step 3: Adjustment value of θ can be calculated[10] by $\theta = \frac{1}{a} - \frac{1}{e^{a} - 1}$, which is denoted as $\theta(k+1)$.

Step 4: If comparison value of $\theta(k)$ and $\theta(k+1)$ more than given threshold value ε, then the value of $\theta(k)$ is replaced by the value of $\theta(k+1)$, the iterative calculation of $\theta(k+1)$ is carried out from Step 1; else the output of a and b are figured out.

The improved calculating method of background value is important for GM(1,1) has more prediction accuracy.

3.3 Exponential Smoothing Improve Grey Model

An improved grey model based on exponential smoothing method is proposed from combination points of chapter 3.1 and chapter 3.2.

The original sequence: $Y^{(0)} = \{y^{(0)}(1), y^{(0)}(2), \cdots, y^{(0)}(n)\}$, which is transformed into smooth sequence according to formula (9): $X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\}$, then the sequence of $X^{(0)}$ is transformed into new sequence of $X^{(1)}$ by using AGO. The parameters of a and b are calculated according to the steps illustrated in chapter 3.2, then $\hat{X}^{(1)}(t+1) = (x^{(0)}(1) - \frac{b}{a})e^{(-at)} + \frac{b}{a}, (t = 1,2,\cdots,n-1)$, at last $\hat{X}^{(0)}(t) = \hat{X}^{(1)}(t) - \hat{X}^{(1)}(t-1) = (1-e^{a})(x^{(0)}(1) - \frac{b}{a})e^{(-at)}, (t = 1,2,\cdots,n-1)$.

The evaluation of improved grey model's accuracy by using t test method or another test method explained in 1 reference.

4 Experiments

The accuracy of improved grey model is compared with which of primary grey model through experiments on production data of one natural gas field of Liaohe Company. After differently application of GM(1,1) and improved grey model based on exponential smoothing method (I_GM(1,1)) calculated the production data from 1995 to 2001 of the company, the comparison results as table 1 and chart 1, the smoothness index of k is 0.652 because sample data presents larger fluctuation.

Table 1　Comparison Prediction Result of I_GM(1,1) and GM(1,1) (Units: $10^4 m^3$)

Production Data		GM(1,1)		I_GM(1,1)	
Year	Production	Prediction	Relative Error(%)	Prediction	Relative Error(%)
1995	99.60				
1996	149.91	134.03	10.59%	138.52	7.60%
1997	193.23	163.64	15.31%	189.74	1.81%
1998	205.20	185.62	9.54%	208.31	1.52%
1999	255.64	219.27	14.23%	253.26	0.93%
2000	304.83	274.19	10.05%	307.03	0.72%
2001	333.62	304.28	8.79%	314.95	5.59%

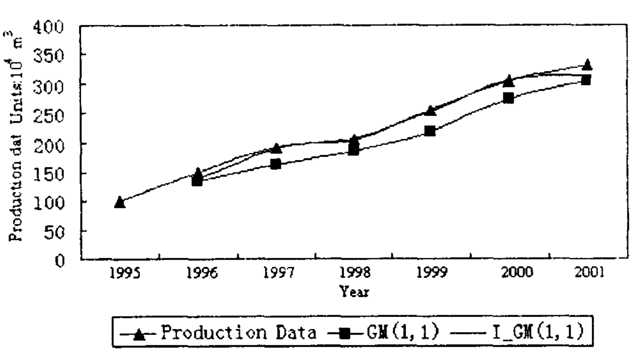

Chart 1　Comparison Prediction Result of I_GM(1,1) and GM(1,1)

According to evaluation of improved grey model's accuracy method explained in preference paper 1, the prediction results of GM(1,1) and I_GM(1,1) both are acceptable, but the I_GM(1,1) has more accuracy than GM(1,1) because the calculating method of grey model background value is improved, besides exponential smoothing method is used to optimize sample data not only makes the most of the information of sample data but also reduces its random.

5 Conclusion

The grey model is one of available method used to predict natural gas production, which is suitable for prediction output of natural gas in short period. There is imprecise prediction problem for the grey model because small sample data can not give complete prediction information[11~13]. An improved grey model is proposed from combination points of exponential smoothing method and primary grey model, in which exponential smoothing method is used to optimize sample data not only makes the most of the information of sample data but also reduces sample data's random, besides the calculating method of grey model background value is improved to transform the calculated production data to be a regular exponential variety sequential. Experiments result shows that improved grey model by exponential smoothing not only has a more reliable forecasting ability, but also is suitable for prediction even if sample data presents larger fluctuation.

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非线性部分中,选择 k = 1,m = 10。

图5为未加延时补偿时系统的阶跃响应曲线,图6为含有延时补偿时系统的阶跃响应曲线。可以看出,由于网络诱导时延的存在,系统的超调量增大,调节时间较长。但采用了预测补偿之后,诱导时延对系统的影响明显减小,系统的动态和稳态性能得到了明显改善。

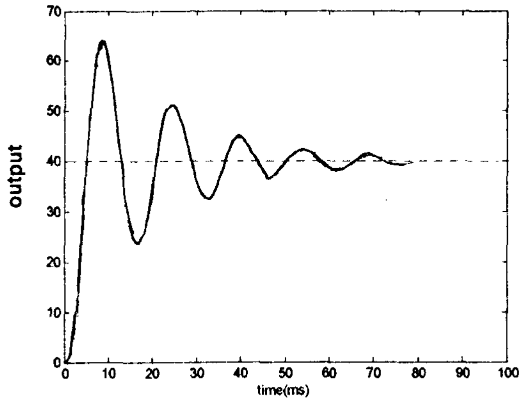

图5　未加预测补偿时的阶跃响应

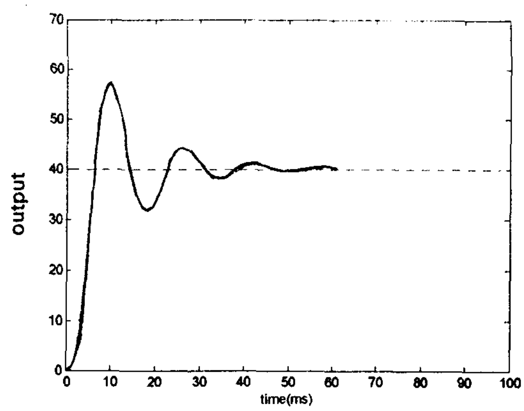

图6　使用预测补偿后的阶跃响应

4　结束语

文中采用了广义预测控制的思想对具有死区输入的 Hammerstein 非线性系统设计了网络预测控制方法。该方法首先设计线性部分的预测控制器,然后对非线性部分求逆来求取预测的控制输入,选取最靠近当前时刻的预测值作为系统的实际输入,以对诱导时延进行补偿。初步的实验结果验证了所提方法的有效性。文中假设了数据包不存在丢失现象,对数据包存在丢失的情况,在今后的研究中将予以考虑。

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