

# 应用灰色动态模型对事故进行预测分析

罗贻乡 罗芳

江汉石油学院,湖北省荆州市,434102

**摘要** 利用灰色动态模型的主要方法和观点,分析企、事业发生的工伤事故(损失工作日),建立灰色数据预测模型GM(1,1)的基本模型和微分方程式,并根据累加生成数列结果,预测事物进一步发生、发展的规律,从而预测其在今后一段时间内的变化。最后对统计实例进行计算和相关关联度分析,精度达88%,拟合程度较好。此方法对企、事业单位的安全生产有一定的指导意义。

**关键词** 灰色动态模型 损失工作日 特征数据 最小二乘法

一个既有时间因素,又有预测因素的模型,不但可以用来分析事物(事件)因果随时间的变化关系,而且可以分析事物的内在联系,从而找出其变化趋势和未来。灰色动态模型GDM(Grey Dynamic Model)是通过时间序列去研究、发现事物变化发展的连续的或离散的的未来时间序列,从而分析事物的变化规律,预测事物今后的发展变化过程,以便及早对事故进行防范或规划决策。

## 1 GM(1,1)灰色预测模型的建立

GM(1, n)灰色数列预测模型是GDM中最重要的基本模型,它与一般建立差分方程的系统理论的差别,在于可以建立起微分方程模型。括号中1表示是一阶, n表示变量的个数。最常用的微分方程GM(1,1),也就是一阶一变量的动态模型。虽然GM(1,1)是GM(1, n)的特例,但它是构成解的最基本的数学预测模型,也是最常用的。GM(1,1)的建模过程如下。

给定研究系统的原始特征数据序列,如灾变中的绝对指标(损失工作日、人员伤亡数、损失值)或相对指标值作为原始数据,记为

$$x^{(0)} = [x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)]。$$

根据文献[1],对初始值(即观测值)作一次累加生成(AGO)处理,即可得到

$$x^{(1)} = [x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)]。$$

当  $n = k$  时,

$$x^{(1)}(k) = \sum_{m=1}^k x^{(0)}(m) \quad (m = 1, 2, \dots, k),$$

$$\text{即 } x^{(1)}(k) = x^{(0)}(1) + x^{(0)}(2) + \dots + x^{(0)}(k), \\ x^{(1)}(1) = x^{(0)}(1)。$$

GM(1, n)一阶微分方程最简单的形式是

$$\frac{d(x)}{dt} + ax = u; \quad (1)$$

式中  $a, u$  为待定系数,需按微分方程的某种方法求解;本文根据文献[2],利用最小二乘法求得预测值参数

$$\hat{a} = \begin{pmatrix} a \\ u \end{pmatrix} = (B^T B)^{-1} B^T Y_N; \quad (2)$$

$$\text{式中: } B = \begin{bmatrix} -1/2[x^{(1)}(1) + x^{(1)}(2)] & 1 \\ -1/2[x^{(1)}(2) + x^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -1/2[x^{(1)}(n-1) + x^{(1)}(n)] & 1 \end{bmatrix}; \\ Y_N = \begin{Bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{Bmatrix}$$

即  $Y_N = [x^{(0)}(2), x^{(0)}(3), \dots, x^{(0)}(n)]^T$ ;  
-1表示矩阵的逆; T表示转矩阵。

在式(1)中,当对象为广义能量系统时可以认为在  $\Delta t \rightarrow 0$ , 即足够小的情形下,变量  $d(t)$  到  $d(x + \Delta t)$  不会出现突变;为此,可取  $d(t) + d(x + \Delta t)$  的平均值作为在变化的  $\Delta t$  这一过程  $dx/dt$  (即  $x$  的1-AGO值)的背景值,或者说用  $1/2[x(k+1) + x(k)]$  作为  $k$  到  $k+1$  这一时刻的预测值是合适的。根据上述原理,GM(1, n)白化形式的微分方程为

$$\frac{dx_i^{(1)}}{dt} + ax_i^{(1)} = b_1 x_2^{(1)} + b_2 x_3^{(1)} + \dots + b_{n-1} x_n^{(1)}。$$

当  $n = 1$ , 即变量为惟一值时,

$$a^{(1)} x^{(1)}(k+1) + a(k+1) = u。$$

对于上式考虑:

$$\begin{aligned}
 &1) a^{(1)}x^{(1)}(k+1) = x^{(0)}(k+1); \\
 &2) \hat{x}^{(1)}(k+1) = 1/2[x^{(1)}(k) + x^{(1)}(k+1)]. \\
 &\text{可得:} \\
 &k=1, x^{(0)}(2) = a\{-0.5[x^{(1)}(1) + x^{(1)}(2)]\} + u; \\
 &k=2, x^{(0)}(3) = a\{-0.5[x^{(1)}(2) + x^{(1)}(3)]\} + u; \\
 &\dots\dots \\
 &k=n, x^{(0)}(n) = a\{-0.5[x^{(1)}(n-1) + x^{(1)}(n)]\} + u.
 \end{aligned}$$

引用矩阵表示为

$$\hat{a} = (B^T B)^{-1} B^T Y_N.$$

这时白化方程的解(即从  $K$  到  $K+1$  次)的累加生成数列预测计算公式为

$$\hat{x}^{(1)}(k+1) = \left[ x^{(0)}(1) - \frac{u}{a} \right] e^{-ak} + \frac{u}{a}. \quad (3)$$

根据上式便可得到  $k+1, k+2, \dots, k+n$  生成数系列,即:

$$\hat{x}^{(1)} = [\hat{x}^{(1)}(1), \hat{x}^{(1)}(2), \dots, \hat{x}^{(1)}(k), \hat{x}^{(1)}(k+1), \dots].$$

### 2 预测模型关联度分析

预测结果与真实值是否吻合,要用预测值与实际值对比,验证其相似程度,即用关联度来判断。

$$\text{关联度 } R = 1/nR_i = \sum_{k=1}^n \zeta(k); \quad (4)$$

式中  $\zeta(k)$  为关联度系数,可按文献[4]求出。

实践证明:  $R > 0.6$  时,模型拟合程度满足要求。

### 3 预测实例分析

某石油企业根据统计部门按国家 GB 6545-86 分类方法统计的损失工作日数据见表 1。

表 1 损失工作日统计值

年份	1996	1997	1998	1999	2000
损失工作日/d	260	310	334	352	359

根据前述原理和表 1 数据建立预测模型:

$$\hat{x}^{(0)} = (260, 310, 334, 352, 359).$$

对  $\hat{x}^{(0)}(k)$  作一次累加生成序列,便可得到 1-AGO 值:

$$\hat{x}^{(1)} = (260, 570, 904, 1256, 1615, 1965).$$

根据式(2)矩阵  $B$  的关系,即可得出  $\hat{a} = \begin{pmatrix} a \\ u \end{pmatrix}$  中的  $a$  与  $u$ 。

运行结果:  $a = 0.0428, u = 294.56$ 。将  $a, u$  值代入式(3),则可得出数列预测模型

$$\hat{x}^{(1)}(k+1) = 6421.23 e^{-0.0428k} - 6111.2.$$

按上式将  $k$  值代入,则可计算出预测值如表 2 所示。

表 2 实际值与计算值的比较

年份	1996	1997	1998	1999	2000	2001*	2002*
$\hat{x}^{(0)}(k)$	260	310	334	352	359	372	382
$\hat{x}^{(1)}(k)$	260	317	333	349	366	385	403
相对误差/%	0.00	2.26	0.30	0.85	1.95	3.45	5.50

说明:带\*号栏的数据为预测值。

然后进行误差关联度分析。根据式(4)关联度分析方法,计算出的关联系数见表 3。

表 3 关联系数

序号	1	2	3	4	5
$\zeta$	1.000	0.912	0.873	0.764	0.853

依式(4)计算  $x^{(1)}$  与  $x^{(0)}$  的关联度

$$\begin{aligned}
 R &= \frac{1}{5} \sum_{k=1}^5 \xi_1 k = \\
 &0.5(1.000 + 0.912 + 0.873 + \\
 &0.764 + 0.853) = 0.881
 \end{aligned}$$

$R$  值在允许范围之内,说明用此种方法分析是有效的,可用作预测系统的分析模型。

### 4 结果分析

1) 采用灰色动态模型(GM)(1, n)预测某些原因尚不明显的事物是有效的,它能克服随机干扰(如事故发生的偶然性),反映事物的规律性。它与回归分析为主的统计型和以指数平滑法递推型相比,有其特有的优势,即无须大量的样板量,也不必具有典型的分布规律。生产过程中的不安全隐患或者危险往往处在一种关系不明确、结果未知、信息不完全的状态,利用灰色动态分析有其独到之处。

2) 数学模型运算看来烦琐,但是都是有规律的运算,比如矩阵运算、矩阵的逆运算、指数运算等;这些运算目前都有标准的运算程序,所以用计算机辅助运算就会使问题简单化。

3) 从表中可以看到,该系统后续 2 年的预测结果成增长趋势,这值得有关部门高度重视,进一步分析产生事故的原因并提出整改措施。

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体的每家公司都应注意审查。

### 4.1 评标准备

在评标工作开始前,应做好以下几项准备工作:

- 1) 做好评标工作计划,健全评标小组的机构,配置相应的工作人员。
  - 2) 编制评标工作程序,确定评标方法。
  - 3) 建立严格的工作制度。
  - 4) 编制评标提纲及必要的评标表格。
  - 5) 认真研究投标文件及相关资料。
  - 6) 确定好评标小组工作地点,确保做好封闭式
- 的评标。

### 4.2 评标步骤

评标工作通常的做法是先按技术、经济、管理及条法分别评审。技术部分则先按专业来评审,然后进行综合评审。评标工作的步骤大致如下。

第1步:检查投标书是否按“投标需知”要求编制、装订、密封与交付。如严重违规,则可视为废标。

第2步:检查投标书中有无明显的数字错误。若有,则评标人可以改正,但要投标者加以确认。有些错误则应交投标者负责改正,但都要遵循一定的工作程序。

第3步:按照统一的评标提纲及表格评审投标书中的内容。

第4步:对投标者提出的建议方案进行认真研究。明确评审结论,是采纳还是拒绝(一般未得到招

标者的认可,投标者不会提出方案)。

第5步:评审投标报价书。

一是要看报价书是否按“投标指南”要求分类分项计算的,有无计算依据。

二是审查总报价,是否符合合同条件。如果总报价高于或低于招标人的总价标底的某个百分率,则有可能视作废标;但是,同时也应审查分项的此百分率,以做出正确的断定。

三是检查投标书中有无重大漏项。如有,则可通知投标者,限期改正。

第6步:在以上工作的基础上进行最终评审。提出中标者的建议,送有关部门审批。

### 4.3 评标注意事项

要做好评标工作,应强调以下几点:

- 1) 要严格执行国家的招标投标法。
- 2) 要坚持封闭性评标,排除一切干扰。
- 3) 不能只注意“低报价”投标书,防止产生倾向性问题。
- 4) 既要注意招标者的利益,也应顾及投标者的利益。两者的利益应该是合理的。

## 参考文献

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with phase fractions derived from physical property measurements. The operating principles of velocity and phase fractions measurements were discussed. Its uncertainties were analyzed in detail. Most multiphase flowmeters can provide phase flow rate measurements with uncertainties of  $\pm 10\%$  relative to the actual flow rate within a limited range of flow rate. For well testing purpose their accuracy may be sufficient. The selection of the most appropriate type must be determined by the conditions to be measured.

Key Words: multiphase flow meter, velocity measurement, phase fractions measurement, selection of type

The Management of JZ 9-3 Oil Field in Winter ..... Zhang Zhongde, Li Jingfeng (41)

Abstract: In winter, the air temperature is chilly, the climate is very bad and the ice on the sea is serious. These bring effect on the production of the whole oil fields in Bohai sea very serious. It's very important that how to strengthen the management on production and facilities of every oil field and make oil field product steadily in winter. Taking JZ 9-3 oil field as an example, this article introduces some experiences on management in winter.

Key Words: winter management, prepare work, wind ice, loading

#### •MANAGEMENT•

The Organization and Management for Design Project of Wenchang 13-1/13-2 Oilfield

..... Chen Rongqi (43)

Abstract: the basic design for Wenchang 13-1/13-2 oilfield, the first large-scale integrated oilfield, was completed independently by China Offshore Oil Research Center. The design project was divided four stages and went through thirty months. This paper describes the organization and management of design project for this oilfield.

Key Words: Wenchang oilfield, design project, organization and management

Re-study for the Parallel Project with the Design and Fabrication of Offshore Platform

..... Xiang Shouan (48)

Abstract: Owing to successful launching of heavy derrick/lay barge "Lanjiang" and its sound engineering activity, we made a conclusion that "the parallel project", which to be used successfully on the "Lanjiang", is to be implemented on our offshore oil platform design and construction. It means the client and manufacture should be invited to take part in the Think Tank from the beginning; the designer client and manufacture should coordinate in the engineering project from A to Z; and the hull and equipment research is to be coordinate as well.

Key Words: parallel project, strategic crisis idea, playing rule

Brief Introduction of Bidding for Engineering Project (first part) ..... Hu Bingyan (51)

Abstract: This article briefly introduced the procedures, methods and main point of bidding work of engineering projects from tender preparation to tender appraisal. The article will help you to understand the important points of bidding work.

Key Words: engineering project, invitation for tender, assessment of bids

#### •SAFETY•

Jet Fire Influence to Pipeline of Offshore Platform ..... Han Shengzhang, Hu Yunchang (53)

Abstract: Simplified method was adopted to analyze the temperature model of vertical pipeline under jet fire loading in marine platform by combing the fire energy with material properties. Satisfied correlation was achieved by comparing the analytical results with the experimental ones. At the same time, the breakage probability of pipeline because of temperature variation was considered. This dissertation would be used to determine the protection measures for pipeline.

Key Words: risk assessment, offshore platform, fire loading, jet fire

Accident Predicted by the Gray Dynamic Model ..... Luo Yixiang, Luo Fang (56)

Abstract: The main process of applying the GDM (gray dynamic model) to predict the event is to build up gray system differential equation model, Gray Model (GM). In this paper, in terms of staff casualty accident, the author uses the gray system predicting method put forward by Deng Julong etc, to build up industrial injury accident (lost man-hour) performance model GM (1,1). Therefore the results show that the matching degree is high, and the GM can be used in industry safety production.

Key Words: gray dynamic model, characteristic data