Journal of Computer Technology and Software
ISSN:2998-2383
Vol. 3, No. 3, 2024

Real-Time Prediction Using a Multivariable Grey Prediction Model

Zelphia Tran[1],

[1]Department of Petroleum Engineering, University of Tulsa, USA

Correspondence should be addressed to Zelphia Tran; zelphia89@uh.edu

Abstract: In recent years, the challenge of managing annular pressure in high-temperature, high-pressure gas wells has become increasingly significant for the global petroleum industry. While extensive research has explored the formation mechanisms and indirect calculation methods of annular pressure, real-time prediction remains underdeveloped. This study addresses this gap by applying grey system theory, specifically grey correlation analysis, to identify key variables affecting annular pressure changes in gas wells. A multivariable grey prediction model was developed to enable early diagnosis and proactive management of abnormal annular pressure. Using 12-hour measured data from a high-pressure gas well in northwest Sichuan, the model demonstrated a maximum prediction error of 0.65%, confirming its effectiveness and providing a novel method for dynamic annular pressure management. The findings underscore the potential of grey system theory in enhancing safety and efficiency in gas well operations.

Keywords: Production safety, Annulus pressure, Grey system theory, Multivariate grey model.

1. Introduction

In recent years, with the large-scale development of high temperatures and high pressure, annulus pressure has become a common problem and safety problem faced by the world's petroleum industry[1]. Many scholars have made an extensive exploration of the formation mechanism and indirect calculation method of annular pressure, but there is still little research on real-time prediction of annular pressure in gas wells. According to the existing understanding, the annular pressure of gas wells in northwest Sichuan is not simply caused by heat, but mainly caused by abnormal sustained casing pressure., with complex and diverse pressure sources. Since Deng Julong first proposed the "grey system" in 1982[2], it has rapidly developed into a new discipline to study the uncertainty of "small data, poor information", in which the grey correlation analysis is an important part of the grey system theory[3]. Aiming at the deficiency of the structure of grey GM (1,1) model, Su Bianping [4]and Chen Xiangdong[5] successively combined the GM (1,1) model, discrete grey prediction model, and the traditional multiple linear regression model in mathematical statistics, and proposed a multivariable grey prediction model.

In conclusion, according to the characteristics of the gas well annulus system, based on existing knowledge, the grey correlational analysis is considered to analyze the main related variables that affect the change of gas well annulus pressure, and on this basis, a multivariable grey prediction model of gas well annulus pressure is established to realize the early diagnosis and active prevention of abnormal annulus pressure, thus providing a new research idea and method for the management of gas well annulus pressure.

2. Grey Correlation Analysis Mechanism

The system characteristic sequence and the correlation factor sequence together constitute the modeling object of the multivariable gray prediction model, so the gray correlation analysis is the basis of establishing the multivariable gray prediction model. The general calculation steps of Deng's grey relational analysis are as follows: (1) Select the system feature sequence and related factor sequence, and conduct dimensionless processing on the data; (2) Find the absolute value sequence of the difference between the corresponding components of the initial value image of the system feature sequence and the correlation factor sequence, and calculate the maximum and minimum values; (3) Calculate the correlation coefficient and average it. On this basis, Liu Sifeng et al[6]. explored the structure and nature of Deng's grey relational analysis model and proposed some improved grey relational analysis methods. Multivariable Grey PredictionMechanism

The modeling object of the multivariable grey prediction model is composed of a system feature sequence and several related factor sequences. The influence of related factors on the development trend of the system is fully considered, which makes up for the shortcomings of the GM (1,1) model with a single structure and limited simulation ability[7]. The steps of establishing a multivariable grey prediction model for the system are as follows: (1) grey accumulation generation and adjacent mean generation for the original sequence; (2) The GM (1,1) model is established for the sequence of relevant factors respectively, and the prediction value of the subsequent time of each relevant factor is obtained; (3) The average relative error is used to test the prediction accuracy of GM (1,1) model. The accuracy inspection level is shown in Table 1. When the accuracy inspection level reaches Level I or Level II, subsequent prediction can be made; (4) The grey multivariable prediction model is established for the system characteristic sequence and the related factor sequence, and the prediction value of the subsequent time of the system is obtained.

Table 1. Reference Table of Average Relative Error Accuracy Test Grade

Accuracy class	One-level	Two-level	Three-level	Four-level
Average relative error α	1%	5%	10%	20%

3. Multivariate Grey Prediction of Annular Pressure in Gas Wells

The principle of new information priority is one of the basic principles of grey system theory, that is, new information plays a greater role in cognition than old information[8]. Based on the grey correlation analysis and the principle of new information priority, this paper establishes a multivariable grey prediction model of gas well annular pressure with metabolic function. The calculation flow chart is shown in Figure 1:Fig. 1 Multivariate Grey Prediction Calculation Flow Chart of Annular Pressure of Gas Well.

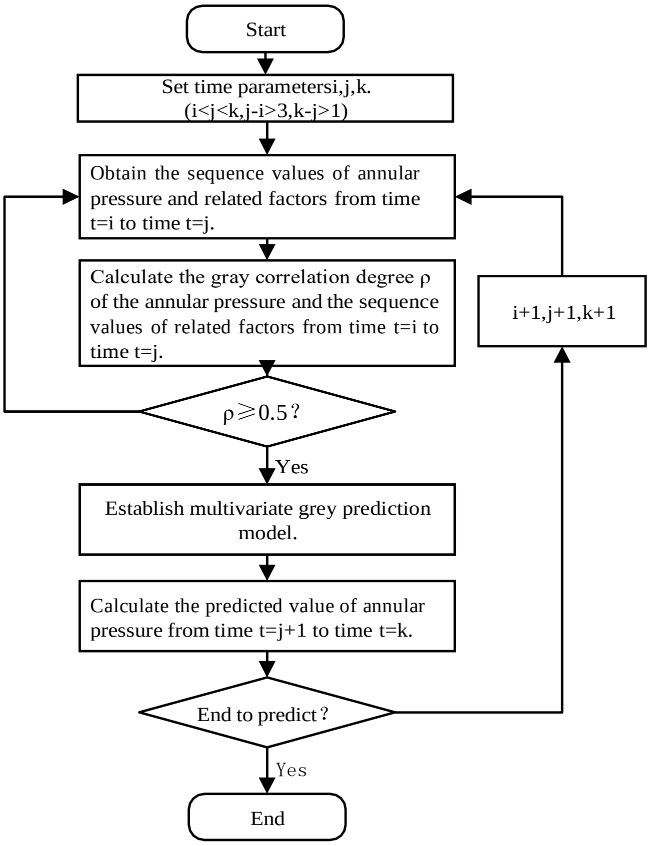

Figure 1. Multivariate Grey Prediction Calculation Flow Chart of Annular Pressure of Gas Well

3.1. Grey correlation experiment

The measured values of annulus A pressure and tubing pressure, wellhead temperature, and gas production for 12 consecutive hours in a day in a high-pressure and high-yield gas well in northwest Sichuan are selected as the experimental data. The interval between each time is 1 hour. The calculation results of the grey relative correlation degree r_{0i}, grey absolute correlation degree ε_{0i}, and grey comprehensive correlation degree $\rho_{0i}\,(i=1,2,3)$ between annulus A pressure and tubing pressure, wellhead temperature, and gas production during the 00:00-06:00 period are shown in Table 2:

Table 2. Calculation Results of Grey Incidence

Parameter	Oil pressure			Wellhead temperature			Gas production		
Association degree type	r_{01}	ε_{01}	ρ_{01}	r_{02}	ε_{02}	ρ_{02}	r_{03}	ε_{03}	ρ_{03}
Relevancy	0.947	0.716	0.832	0.946	0.890	0.918	0.889	0.500	0.694

It can be seen from the above table that the calculated value of each gray comprehensive correlation degree is greater than 0.5, indicating that these three factors are the interpretation variable sequences with high correlation with the annular pressure of gas well A during the period 00:00-06:00.

3.2. Multivariable Grey Prediction Experiment

Firstly, GM (1,1) model is established for oil pressure, wellhead temperature, and gas production sequence in the period of 00:00-06:00, and precision inspection is carried out. Through inspection, the precision grade of average relative percentage error of grey GM (1,1) prediction of oil pressure and wellhead temperature in the period of 00:00-06:00 reaches Grade I, and the precision grade of average relative percentage error of grey GM (1,1) prediction of gas production reaches Grade II, so it can be used for short-term prediction. Therefore, the prediction values of various factors at 07:00-11:00 can be obtained through the established grey GM (1,1) model. The calculation results are shown in Table 3:

Table 3. Prediction Values of Relevant Factors 07:00-11:00

Time	Oil pressure (MPa)	Wellhead temperature(°C)	Gas production(m3)
07:00	55.674	33.894	202095.417
08:00	55.178	34.182	204973.519
09:00	54.688	34.471	207892.608
10:00	54.201	34.764	210853.269
11:00	53.719	35.058	213856.094

The multivariable grey prediction model is established for the A annulus pressure sequence and the relevant factor sequence. The data from 00:00-06:00 is used as the basis for the least squares estimation of the model parameters, and the data from 07:00-11:00 is used as the basis for testing the prediction effect of the model. The prediction results of the A annulus pressure from 07:00-11:00 are shown in Table 4, which are compared with the measured values and plotted as shown in Figure 2.

Table 4. Prediction Results of A Annular Pressure 07:00-11:00

Time	A predicted value of annulus pressure (Mpa)	An actual value of annular pressure (Mpa)	Error (%)
07:00	40.429	40.401	0.07%
08:00	40.634	40.565	0.17%
09:00	40.837	40.723	0.28%
10:00	41.039	40.853	0.46%
11:00	41.241	40.975	0.65%

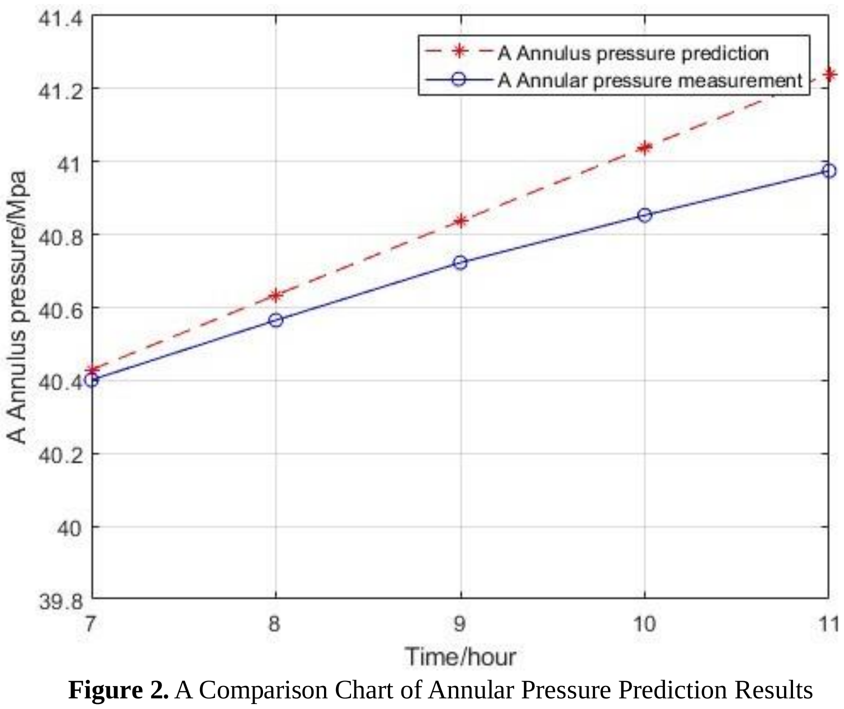

Figure 2. A Comparison Chart of Annular Pressure Prediction Results

4. Conclusion

Real-time prediction of annular pressure in gas wells is of great significance to ensure safe production and improve production efficiency. Based on the grey system theory and the idea of new information priority, a multivariable grey prediction model for the annular pressure of gas wells with metabolic function is proposed by considering the influence of various related factors on the changing trend of annular pressure of gas wells and combining the results of grey correlation analysis. Taking the 12-hour measured data of A annulus pressure, oil pressure, wellhead temperature, and gas production of a high-pressure and high-yield gas well in northwest Sichuan as an example, the maximum prediction error is 0.65% through comparison and analysis of the model prediction results and the measured data, which verifies the effectiveness of the prediction model. The research results verify the feasibility of applying grey system theory to the dynamic prediction of annular pressure in gas wells and provide a new research idea and method for the management of continuous annular pressure.

References

[1] Zhu Dajiang. Study on Annular Pressure Mechanism of Gas Wells [D]. Southwest Petroleum University, 2014.

[2] Zhang Ke. Research on Matrix Grey Correlation Analysis Modeling Technology [D]. Nanjing University of Aeronautics and Astronautics, 2010.

[3] Deng Ju-Long.Control problems of grey systems[J].Systems and Control Letters,1982,Vol.1: 288-294.

[4] Su Bianping, Cao Yanping, Wang Ting. Grey prediction model of multi factor time series [J]. Journal of Xi'an University of Architecture and Technology (Natural Science Edition), 2007, Volume 39 (2): 289-292.

[5] Chen Xiangdong, Wang Bin. Multi factor Grey Prediction Model and Its Application [J]. Mathematical Practice and Understanding, 2012, (1): 80-83.

[6] Liu Sifeng, Guo Tianbang. Grey system theory and its application [M]. Kaifeng: Henan University Press, 1991.

[7] Zeng Bo, Yin Xiaoyong, Meng Wei. Practical Grey Prediction Modeling Method and Its MATLAB Program Implementation [M]. Beijing: Science Press, 2018.

[8] Liu Sifeng, et al. Grey System Theory and Its Application 8th Edition [M]. Beijing: Science Press, 2017.