The Application of Grey Relational Method on Well Productivity Prediction

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ABSTRACT

In this paper, with grey relational method and test data of 7 wells in B field, the relational sequence is solved when production of well test is regarded as reference sequence and other influencing factors are regarded as factor sequences, the influencing degree of each factor is quantized and effective permeability, formation thickness, production pressure difference, skin factor, reserves abundance are selected as the main control factors. In order to ensure the accuracy and avoid disturbance, the main control factors is processed by multiple linear regression model and productivity prediction model is acquired, the model is tested to be high accuracy when applied in new wells productivity forecast. The research results show that the productivity prediction model is able to guide rapid evaluation of well productivity in overseas oilfield development.

KEYWORDS: productivity forecast; grey relational method; multiple linear regression; prediction formula

INTRODUCTION

Well Productivity Prediction is very important in oil field development and affects the result of oilfield technically and financially. The ordinary ways to confirm well productivity, such as formation testing, well testing and simulation, usually take a long time, which delays the development of overseas oil field during the contract, so rapid evaluation method is needed.

The grey relational method has been used in many fields and has been proven successful (Luo Dang&Liu Sifeng. 2005, Shui Naixiang&Dong Taiheng&ShaZhen, 1992, Zhu Baozhang, 1994 , Wang Qingyin, 1989, 6. Zhang Shaoling,&Zhang Guoliang, 1996 Sun Xiaodong&Jiao Yue&Hu Jinsong. 2005). This article chooses overseas B oilfield as the objective. Production data of well test is regarded as reference sequence and other influencing factor are regarded as factor sequence when grey relational method is used. The factor with bigger influencing degree is selected to build forecast model for B field, which used for developing strategy and programing development project.

PHILOSOPHY OF GREY RELATIONAL METHOD

Grey relational analysis is created by Deng Julong in 1985(Deng Julong, 1990) and other experts also have done a lot of research on it. Refered to the philosophy of grey relational method, grey degree is used to quantized the relationship between two factor belonging to two different systems and changing with time and objectives. Grey degree is high if two factors have similar developing trends, otherwise grey degree is low. In other words, grey relational analysis is a method that based on semblance of factors to measure the relevant extent between them.

Grey relational analysis doesn't have strict requirement of sample size and doesn't have to assume models in advance. Computational process is simple and the result is compatible with qualitative analysis in many professions, which is high accuracy and can be used widely.

Coefficient of grey relational method

Reference sequence is as following,

$$X_0 = \{X_0(k), k = 1, 2, \cdots, n\} \tag{1}$$

Factor sequence is following:

$$X_i = \{X_i(k), k = 1, 2, \cdots, n\} (i = 1, 2, \cdots, m)$$

The coefficient of grey relational between X_0 and X_i in K point is:

$$\zeta_i(k) = \frac{\underset{i}{Min}\,\underset{k}{Min}\,\Delta_i(k) + \rho\,\underset{i}{Max}\,\underset{k}{Max}\,\Delta_i(k)}{\Delta_i(k) + \rho\,\underset{i}{Max}\,\underset{k}{Max}\,\Delta_i(k)} \tag{2}$$

ρ is resolution ratio which only influences numerical values, it can't change the order of relational. It is universally accepted that ρ is 0.5. (Lv Feng, 1997, Sun Zuoan &Wang Qi. 1997 Guo Hong, 1985 , 11. Shen Maoxing & Xue Xifeng, Zhang & Xiaoshui , 2003, Zhu Baozhang)

The grey relational coefficient between X_i (k) and relating X_0(k) is

$$\zeta_i = \{\zeta_i(k), \quad k = 1, 2, \cdots, n\} \tag{3}$$

Relational degree and order

When relational coefficient of each factor is get, it covers a large range of numerical values and expresses confusing information. So it should be processed into standardized comprehensive value to compare with each other, this value is called relational order. The usual way to do this is to evaluate the average value of relational coefficients.

$$\gamma_i = \frac{1}{n}\sum_{k=1}^{n}\zeta_i(k) \tag{4}$$

The relational coefficient γ_i stands for goodness of fit between reference sequences and factor sequences. Bigger relational coefficient value, more fit between these sequences. When relational coefficient is arranged from large to small, relational order is get.

FIELD APPLICATION

General situation of formation testing in B oilfield

Significant breakthrough has been made in B field during the period of exploration. 12 reservoirs have been discovered and 7 of them have been testified by well logging that they can produce crude oil in industrial grade. The production of well test is chosen as reference sequence

because it is the principal index for productivity forecast. The factors that affect well productivity are chosen as the factor sequences. Well test production and relating factors are shown in **Table 1**.

Table 1: Well test production and relating factors of 7 wells in B field

Well name and Parameters	RS-11	B1-8	ME-1	LE-2	RS-10	PS-3	BE-2
Well test production, m^3/d	341.77	127.99	53.99	494.78	289.75	484.53	384.17
Initial pressure, MPa	13.36	17.44	11.07	8.26	15.41	10.63	16.52
Flowability, mD.m/mPa.s	44706	1821	5288	38217	3612	46497	1831
Formation factor, mD.m	114000	15300	21100	120000	9210	146000	8530
Effective permeability, mD	1940.0	391.0	118.0	3410.0	54.0	831.0	535.0
Skin factor, Frac	-1.88	1.28	198.00	5.24	17.80	10.70	0.07
Reservesabundance,$10^4m^3/km^2$	181.77	218.04	23.35	136.58	181.77	181.77	84.67
Viscosity, mPa.s	10.40	51.59	18.00	18.40	22.00	10.80	35.23
Formation thickness, m	58.20	68.50	74.10	100.50	147.30	173.50	16.10
Pressure drop, MPa	2.3	4.1	3.7	2.54	1.8	3.0	3.2
Porosity, Frac	6.20	5.50	5.50	4.10	5.50	4.70	7.10

Relational coefficient and relational order

All data is substituted into the formula (1),(2) and (3) for calculating them to get the relational coefficients (**Table 2**) between well test production and relating factors. All relational coefficients are substituted into the formula (4) to get relational order (**Table 3**). The relational order is obtained by using Deng grey relational analysis. Also absolute grey relational analysis, relative grey relational analysis and comprehensive grey relational analysis are applied to calculate the relational coefficient to test and verify the result.

Table 2: Relational coefficients between reference sequence and factor sequences

Parameters	RS-11	B1-8	ME-1	LE-2	RS-10	PS-3	BE-2
Initial pressure, MPa	1	0.9827	0.9874	0.9845	0.9942	0.9883	0.9979
Flow ability, mD.m/mPa.s	1	0.9937	0.9992	0.9889	0.9857	0.9929	0.9799
Formation factor, mD.m	1	0.9955	0.9995	0.9926	0.9857	0.9974	0.9805
Effective permeability, mD	1	0.9967	0.9982	0.9942	0.9847	0.9816	0.9842
Skin factor, Frac	1	0.9804	0.3333	0.9257	0.8364	0.8812	0.9785
Reserves abundance, $10^4m^3/km^2$	1	0.9846	0.9994	0.987	0.9971	0.9921	0.9877
Viscosity, mPa.s	1	0.92	0.971	0.9939	0.9765	0.9929	0.9588
Formation thickness, m	1	0.985	0.9793	0.9947	0.9691	0.9712	0.9842
Pressure drop, MPa	1	0.974	0.9732	0.9935	0.9988	0.9979	0.995
Porosity, Frac	1	0.9904	0.9864	0.9853	0.9993	0.9876	0.9996

Table 3: Relational order between well test production and factors

Parameters	Formation factor	Reserves abundance	Porosity	Flow ability	Effective permeability	Initial pressure	Pressure drop	Formation thickness	Viscosity	Skin factor
Relational order	0.953	0.9026	0.8926	0.8715	0.7914	0.7807	0.7603	0.6834	0.5733	0.5479

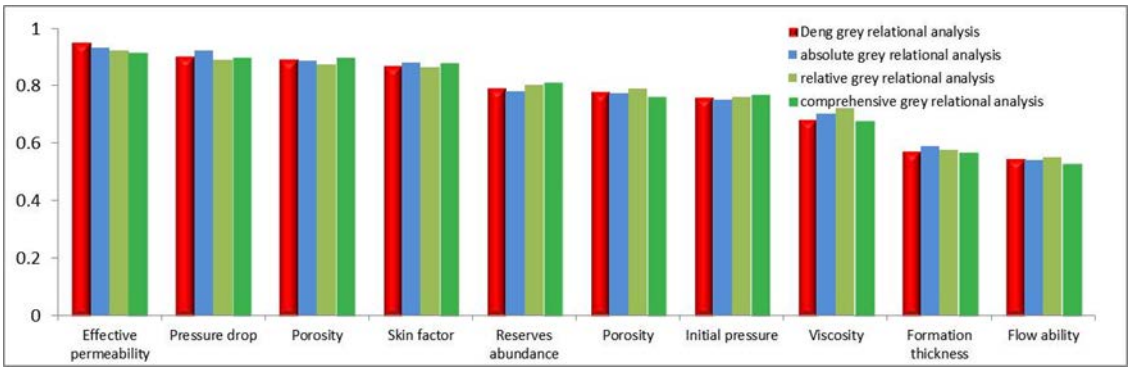

Figure 1: The relational order of 4 grey relational analysis

The result (**Figure 1**) shows that the grey relational order of 4 methods is basically same. The main factors influencing the well test production are effective permeability, formation thickness, producing pressure drop, skin factor, reserves abundance in descending order of importance. Priority should been given to these factors when predict the productivity. These chosen 5 factors are similar to those chosen by qualitative analysis.

Prediction model and results

According to Darcy law, the well production is in linear relationship with effective permeability, formation thickness, producing pressure drop, skin factor, reserves abundance, so it is reasonable to apply multiple linear regression model to find the relationship between them.

Assumed that:

$$Q_{Test} = b_1 k + b_2 h + b_3 \Delta p + b_4 S + b_5 l \tag{5}$$

The results of the coefficients are:

$$b_1 = 1.0318, b_2 = 1.2867, b_3 = 0.7280, b_4 = -2.5077, b_5 = 0.0056 \tag{6}$$

So

$$Q_{Test} = 1.0318k + 1.2867h + 0.7280\Delta p - 2.5077S + 0.0056l \tag{7}$$

The productivity of B1-5, RS-3, BE-3 is predicted by the model and the results (**Table 4**) is very close to actual value, which indicates that the model is high accuracy and applicable in B field.

Table 4: The basic factors, predicted productivity and forecast error of 3 new wells

Well name	Effective permeability	Formation thickness	Pressure drop	Skin factor	Reserves abundance	Well test production	Predicted productivity	Forecast error
B1-5	214.5	23.0	2.3	36	56	155.4	162.6	4.65%
RS-3	185.6	35.2	1.9	23	40	171.4	179.8	4.90%
BE-3	308.4	29.4	1.7	16	63	304.5	317.5	4.27%

DISCUSSION

The grey relational method can be found in many fields. when applied in field productivity forecast, it is able to select the main influencing factors which can be used in the multiple linear regression model. In this way, the principal contradiction is seized and interference factors are eliminated to simplify the process of prediction. Also the sequence of importance of these factors is get to guide the new well placement.

Multiple linear regression model is used to form the prediction model because the production of wells is in linear relationship with the main influencing factors according to the Darcy law. The predicting results of 3 new wells show that the model is high accuracy.

The prediction model is inferred from B field and is characteristic for B field, so it can be used in the other oil fields. The grey relational method is applicable in other field.

CONCLUSIONS

1) The grey relational method can quantize the influencing extent of reservoir factors and select the main influencing factors.
2) The main influencing factors are effective permeability, formation thickness, producing pressure drop, skin factor, reserves abundance which are same with those deducted from qualitative analysis.
3) The prediction model is tested by 3 new wells and the accuracy is within 5%, so it is successful in forecasting the productivity of oil well in B field and can be used in following work.

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