Overflow Prediction Method Using Fuzzy Expert System

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Abstract

In the process of drilling, some drilling accidents such as overflow will often happen, which in turn triggered a series of problems due to the factors such as geology or improper construction .Therefore, it is particularly important to do the early prediction for the abnormal condition in the process of drilling. In order to achieve this purpose, this paper puts forward a prediction method of the overflow based on fuzzy expert system. The reasoning algorithm and formulas are given, the method clarifies the function relation between the measurement parameters and the early warning result, constructs the knowledge base of the accident model, it can make the system has great flexibility and adaptability. It shows that the method can meet the application requirements for accuracy and has a good application prospect by using field data to validate the prediction method..

Keywords

drilling exception; fuzzy expert system; overflow; prediction.

1. Introduction

The goal of the oil drilling is the safety, high speed and high efficiency of the drilling progress, which can largely save the drilling cost[1]. In order to avoid the happen of the drilling accident, it will be given high attention to the abnormal situation such as overflow in the process of drilling. And the forecasting methods of overflow such as application of neural networks have also been put forward. But the inaccuracy of prediction method will bring huge risk for drilling, single and vulgar method no longer applies to the drilling engineering which is more and more tend to be intelligent. And the drilling is a complicated project, there will be multiple conditions happened in the process of drilling, therefore, there are many parameter factors need to be considered. And it is particularly necessary to use the data-mining technology to get the best characterization of the data in the collected drilling data, constantly dig out the intrinsic relationship between the object of study, eventually establish the rules to deal with problems. This paper apply the forecasting method of overflow based on the fuzzy expert system, on the basis of integrating the fuzzy mathematical theory methods and fuzzy expert system[2], we take optimization selection of the collected abnormal drilling parameters, and find effective relationship models which have potential value and easy to understand so that the prediction method for the overflow will be established.

2. The Occurrence Mechanism and Prediction Method of Overflow

2.1 The Overflow Occurrence Mechanism

Overflow has a variety of reasons, drilling in the abnormal high pressure formation, a lot of formation fluid get into the wellbore and return to the surface; Drilling fluid insufficient supplied so that the drilling fluid column height is reduced, resulting in a decline in wellbore fluid column pressure and formation fluid get into the wellbore; Or under the condition of nearly balanced pressure drilling, the mud pump stops circulating, then the circulating pressure loss which has a balance effect on the formation pressure disappear, it causes that the bottom hole pressure is less than the formation

pressure and the formation fluid invades into the wellbore and so on. All above will lead to the formation of the overflow[3].

2.2 The Overflow Prediction Method

The prediction method of overflow mainly covered the gas measurements for gas cut, the LWD overflow test, etc. Although they have sensitive response, the emergency measures time is limited in the field, the occurrence time and degree of overflow will not be evaluated and so on; And in the early detection methods, the mud pit page test and the flow difference value overflow test have low precision, especially the mud pit page method is not suitable for use on the floating drilling device; The drilling parameter abnormal change test and the flow test have many influence factors, they are difficult to estimate the overflow, and only suitable for drilling conditions. On the basis of the technology of Doppler measurement method[4] and the drilling prediction method based on neural network algorithm, we can get early prediction for gas cut to a certain extent, but we can also ignore the drilling parameters itself is uncertain factors in conjunction with other methods, can't use the classic theory of logic to deal with, if so it is bound to cause a certain deviation and lead to non-ideal results.

3. The Overflow Warning Method Research Based on Fuzzy Expert System

There are a series of complicated cases and a large number of collected data in the process of drilling, and these data parameters exist uncertainty, we need to dig out the valid data from the collected data. Generally, the problems contain of uncertainty have randomness and fuzziness. Existing expert system and fuzzy system have their own limitations, and the introduction of fuzzy mathematics theory and method with the fuzzy expert system to simulate the expert knowledge can solve practical problems.

3.1 The Fuzzy Expert System and The Reason of Application

Fuzzy Expert System is a kind of beyond the expert system based on binary logic [5] and it is the organic combination of expert system and fuzzy logic reasoning. Expert knowledge experience uncertained and fuzzy by the knowledge expression form of fuzzy subset and fuzzy rules was stored in its repository. The results of fuzzy reasoning calculation can be obtained by the way of reasoning calculation of the approximate matching fuzzy rules, and the fuzzy technology are adopted both the knowledge representation and knowledge process.

The result of drilling overflow intelligent prediction applied in the Fuzzy Expert System is:

1)It is highly difficult to establish the very precise overflow prediction mathematical model due to the characteristics of complexity, fuzziness, randomness and nonlinear of the overflow.

2) In the process of drilling, the deficiency of adjacent wells data as well as the pattern recognition method based on sample information which has certain limitations, but the experience of overflow prediction knowledge of drilling experts cannot be restricted.

3)Not only the condition of comprehensive logging parameters variation exists certain fuzziness, but the knowledge experience of drilling experts also has the fuzziness when overflow occurs[6-7].

Because of the superior performance of the Fuzzy Expert System, the overflow intelligent warning process based on Fuzzy Expert System is shown in figure 1.

3.2 The Overflow Prediction Model Based on Fuzzy Expert System

The uncertainty and complexity of drilling accident diagnosis and identification will be ignored by classical logic which cannot express the parameter variation exactly and effectively in dealing with the problem of uncertainties[8].

Fuzzy Expert System adopted layering idea in this paper in order to avoid the problem of "dimension disaster" derived from monolayer model and missing effective data when using monolayer comprehensive evaluation. The overflow prediction model based on Fuzzy Expert System is shown in figure 2.

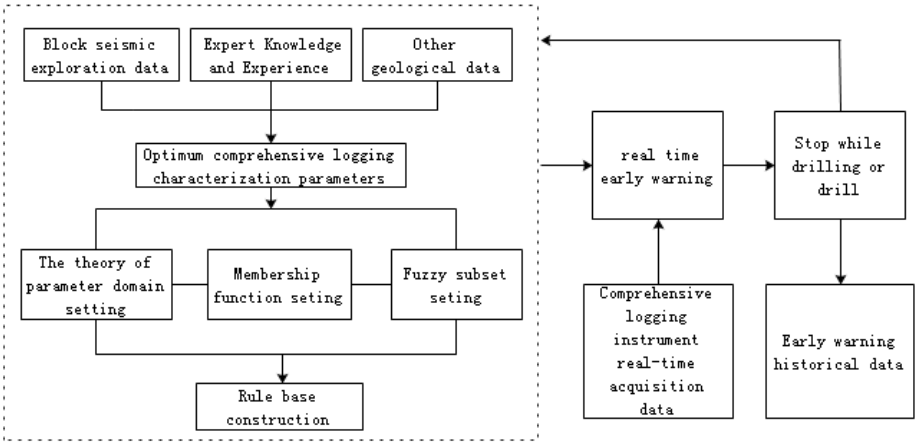

Figure1 The process of overflow intelligent warning based on the Fuzzy Expert System

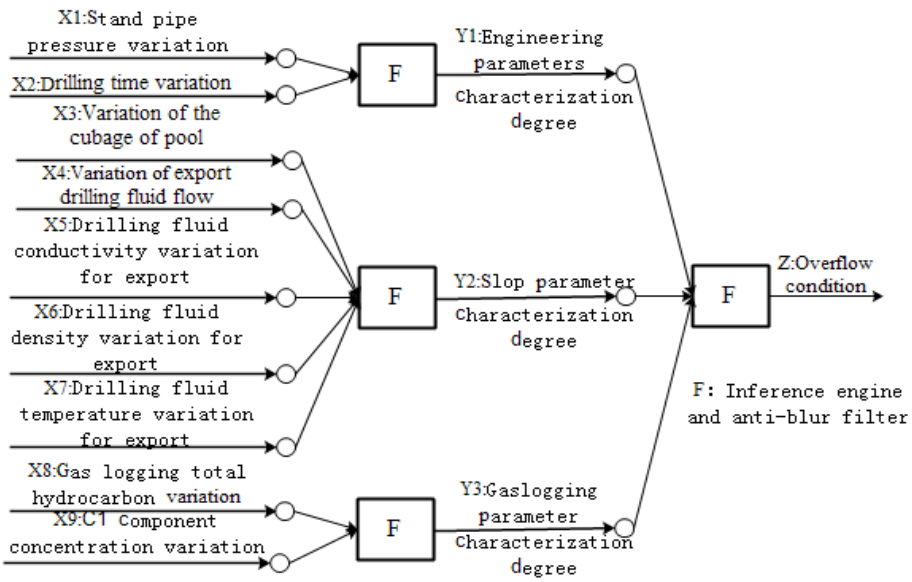

Figure2 The overflow prediction model based on Fuzzy Expert System

Secondly, the method of design of bottom input parameter universe consists of the variation of standpipe pressure and gasometry omni-hydrocarbon and so on, The measurement parameter variation should be established as [0,xf], if the maximum range is xf. Suppose the maximum range of standpipe sensor of comprehension well logging instrument is 100, the standpipe pressure variation universe should be set to [0,100]. In addition, the unverse of both the layers of output parameter and toplet input parameter such as engineering parameter characterization degree are installed as [0,1].

3.3 Characterization Parameter Optimization

Firstly, the research based on a large number of data and whose data from the field, characterization parameters summarized are closely related to the overflow, include standpipe pressure, drilling time variation, the cubage of pool and export drilling fluid flow , conductivity, density and temperature output, gasometry omni-hydrocarbon and the content of C1. In the case of overflow, each rangeability of characterization parameters are intently associated with the degree of the overflow when occurring.

The proposed overflow prediction model based on Fuzzy Expert System is divided into two layers. There are three modules in the bottom : engineering parameter evaluation module consists of the input as which regard the standpipe pressure variation and drilling time variation, as well as the output as which consider engineering parameter characterization degree; mud parameter evaluation module includes both the input as which deemed the variation of the cubage of pool and export drilling fluid flow , conductivity, density and temperature and the output as which take mud parameter characterization degree, gasometry parameter evaluation module consists of the variation of

gasometry omni-hydrocarbon and C1 component concentration, which regard as the input, meanwhile, universe parameter characterization degree is taken as the output. Comprehension evaluation module is made of the characterization degree of engineering parameter, mud parameter, gasometry parameter as the input and the result of overflow predication as the output.

3.4 Linguistic Variable and Membership Function Design

In this paper, the input and output parameters of Fuzzy Expert System uses three hierarchies, namely the language variable is set to {L (low), M (middle), H (high)}, at the same time, choose trapezoidal function as membership function, the expression as shown in type (1).

Trapezoidal membership function expression:

$$\mu(x;a,b,c,d)=\begin{cases}0, x<a;\\ \dfrac{x-a}{b-a}, a\le x\le b;\\ 1, b\le x\le c;\\ \dfrac{x-c}{d-c}, c\le x\le d;\\ 0, x>d\end{cases}$$

Type: a, b, c and d are real numbers.

Stand Pipe Pressure Variation Degree of characterization and engineering parameters, for example, is the fuzzy subset distribution as shown in Figure 3 and 4, respectively, the starting value of Fuzzy Subset can make appropriate correction according to the actual demand.

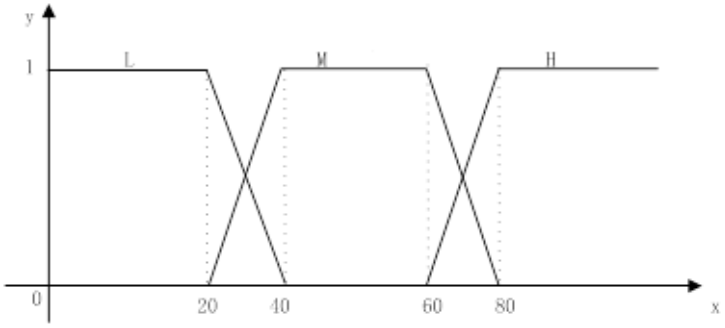

Figure 3: Stand Pipe Pressure membership function distribution

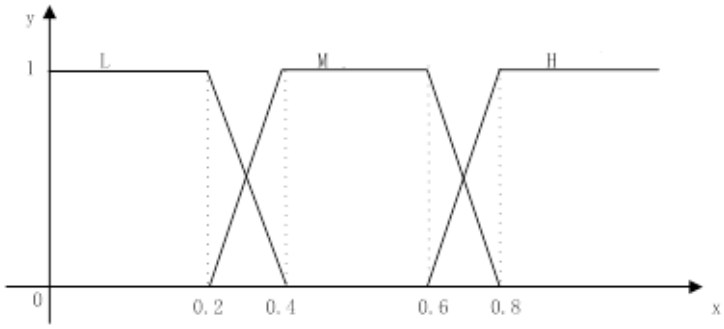

Figure 4: Engineering parameters characterization degree membership function distribution

3.5 Establishment of the Fuzzy Rule Base for Overflow Prediction Model of Fuzzy Expert System

Fuzzy rules is a kind of simulation for reasoning process, is a kind of similar to the representation of human language, mainly by the conjunction relationship such as the if - then, else if, and etc. Generally, Mamdani Fuzzy Rule is:

$$R^i\text{:if x1=}A_1^i\text{ and x2=}A_2^i\text{ ……and xj=}A_j^i\text{ then }y^i=H^i \qquad (2)$$

Type: xj represents jth input variable (j=1,2,…,k); A_j^i represents fuzzy rules of xj; y^i represents ith rule corresponding local output; H^i represents fuzzy rules of y^i.

In this paper, the evaluation of two layer fuzzy expert system for the Overflow Intelligent Advanced Warning Model, the fuzzy rule base including the underlying degree of engineering parameter characterization rule base, mud parameter characterization rule base, degree of gas logging parameters characterization rule base and at the top of the overflow rule base. The Overflow Intelligent Advanced Warning Model Fuzzy Rule Base as shown in table 1.

Table 1: The Overflow Intelligent Advanced Warning Model of Fuzzy Rule Base

The Underlying Rule Base	Engineering Parameter Characterization Rule Base	IF X1=L and X2=L Then Y1=L
		……
		IF X1=M and X2=M Then Y1=M
		……
		IF X1=H and X2=H Then Y1=H
	Mud Parameter Characterization Rule Base	IF X3=L and X4=L and X5=L and X6=L and X7=L Then Y2=L
		……
		IF X3=M and X4=M and X5=M and X6=M and X7=M Then Y2=M
		…… ……
		IF X3=H and X4=H and X5=H and X6=H and X7=H Then Y2=H
	Gas Logging Parameter Characterization Rule Base	IF X8=L and X9=L Then Y1=L
		……
		IF X8=M and X9=M Then Y1=M
		……
		IF X8=H and X9=H Then Y1=H
The Top Rule Base	Overflow Characterization Rule Base	IF Y1=L and Y2=L and Y3=L Then Z=L
		……
		IF Y1=M and Y2=M and Y3=M Then Z=M
		……
		IF Y1=H and Y2=H and Y3=H Then Z=H

The fuzzy expert system makes use of parameters variation through fuzzy variables generated to activate the fuzzy inference rules, finally additivity principle of fuzzy mathematics in the form of subordinate function minimization superposition results, the process of evaluation results is obtained [9]. Layered fuzzy expert system is put forward in this paper, and the first to model the underlying reasoning and blur calculates the underlying calculation results, the calculation result and the underlying top-level reasoning and fuzzy input model, and eventually inference conclusion.

4. Field Application

On the basis of this paper depends on the data mining theory of fuzzy reasoning's drilling abnormal prediction method study, according to the XX well in an oilfield which overflow occurs in 1374.9 m to 1434.3 m due to water invasion situation, choose the interval of comprehensive logging data as the basic data, and do application test of the research methods.

Before testing, according to XX well's previous seismic exploration data, the drilling data of other exploratory well in this block and the expert's knowledge in the field drilling to conducted a

comprehensive analysis, according to research methods described herein, and on the basis of setting up reasonable logging parameters' variation and fuzzy subset the fuzzy rule base is established, to set up the knowledge base of overflow's prediction which apply to the interval. Application of this paper's research to test calculation, the well segment basic data and results of the XX well's 1374.9 m - 1434.3 m and test results are shown in Table 2, Table 3, Fig. 5.

Table 2 XX well measured logging data

serial number	Pipe Pressure (MPa)	drilling time (min/m)	Tank Volume (m3)	inlet flow (L/s)	export flow (L/s)	inlet conductivity (s/m)	export conductivity (s/m)	inlet density (g/cm3)
1	13.254	8.1	180.0	22.8	22.9	0.62	0.62	1.15
2	13.775	8.1	180.2	22.9	23.0	0.63	0.65	1.14
……	……	……	……	……	……	……	……	……
12	14.745	7.9	184.5	22.8	23.2	0.62	0.71	1.14
13	14.557	7.9	184.9	22.7	23.2	0.63	0.74	1.15
14	13.821	7.8	185.0	22.8	23.4	0.62	0.74	1.15
15	13.565	7.8	185.4	22.8	23.5	0.62	0.77	1.15
……	……	……	……	……	……	……	……	……
28	14.845	7.7	197.7	22.8	24.1	0.62	0.77	1.14
29	13.325	7.6	198.8	22.8	24.3	0.63	0.79	1.15
30	14.582	7.6	199.5	22.9	24.4	0.62	0.80	1.15

Table 3 part of XX well measured logging data and the overflow warning test results

serial number	export density (g/cm3)	inlet temperature (℃)	export temperature (℃)	gas logging total hydrocarbon (ppm)	C1 composition (ppm)	Fuzzy Expert System output	early warning results	real situation
1	1.11	40.12	41.02	0	0	0.25	overflow exception	overflow
2	1.10	40.11	41.87	0	0	0.78	overflow	overflow
……	……	……	……	……	……	……	……	……
12	1.08	40.12	42.23	0	0	0.88	overflow	overflow
13	1.08	40.12	42.25	0	0	0.34	overflow exception	overflow
14	1.07	40.12	42.74	0	0	0.37	overflow exception	overflow
15	1.07	40.11	43.26	0	0	0.70	overflow	overflow
……	……	……	……	……	……	……	……	……
28	1.07	40.12	44.85	0	0	0.88	overflow	overflow
29	1.06	40.11	45.10	0	0	0.28	overflow exception	overflow
30	1.06	40.12	45.56	0	0	0.91	overflow	overflow

Obtained from table 2 and table 3 overflow warning system based on fuzzy expert system in XX well in 1374.9 m to 1374.9 m's overflow of the accuracy is high, predicting results was consistent with actual situation, and can meet the requirements of field application.

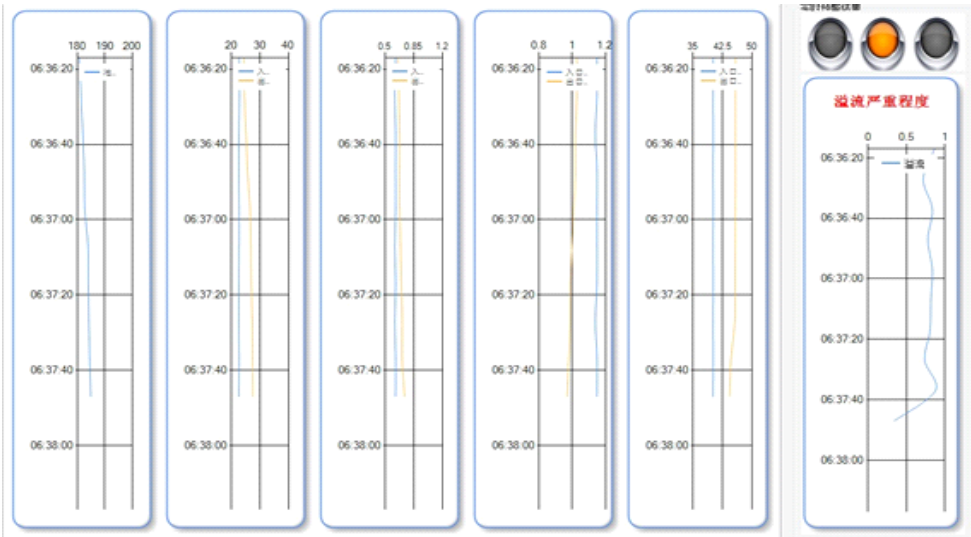

Figure 5 the real-time curve of XX well's mud logging and the overflow warning test results

5. Conclusion

1)For uncertainty of drilling's abnormal factors, using fuzzy reasoning mind can represent parameter's changing more efficiently ,and make it more efficient than using the theory of classical logic conclusion.

2)The core of Mamdani fuzzy reasoning rules' hierarchical fuzzy comprehensive evaluation method to solve the several explosion problem of "dimension disaster", and the problem of losing a lot of single evaluation information when single evaluation cause by taking a small operation.

3)Through the field data validation shows that the research of the overflow prediction method based on fuzzy expert system in this paper which can predict effectively and satisfy the demand of field application.

References

[1] WuJunjie. Monitoring of drilling engineering accident and early warning method[J] .Mud Logging Engineering, 2006,17(1):53-55,70.

[2] Wang Baoyi, Zhang Baosheng, Fei Yanguang. A drilling troubles expert system based on case-based reasoning[J]. Journal of the University of Petroleum, China, 2005,29(6):123-126.

[3] Luo Yangyang. Research and design of early overflow leakage ground monitoring and diagnosis system[D].Chengdu: Southwest Petroleum University,2004.

[4] Sui Xiuxiang, Liang Yufeng, Li Tieming. Early Monitoring of the Gas-Cut in Deepwater Riser Based on Doppler Measuring System[J].Petroleum Drilling Techniques,2014(5),90-94.

[5] Tian Yingzhong. Research and Application of Fuzzy Expert System Based on Vague Sets[D].Wuhan: Huazhong University of Science and Technology,2004.

[6] Zhuo Lubin, Ge Yunhua,Wang Haige. Early kick detection methods for deepwater drilling and its future development[J].Oil Drilling&Production Technology,2009(1).

[7] Don Reitsma, SPE, @balance - A Schlumberger Company. Development of an Automated System for the Rapid Detection of Drilling Anomalies using Standpipe and Discharge Pressure [A]. SPE/IADC 140255 2011,American,2011.

[8] Chen Shuili, Li Jinggong, Wang Xianggong. Theory and application of fuzzy set[M].Beijing: Science Press,2005.

[9] Sun Zhongchang. Technology of drilling abnormal prediction[M].Beijing: Petroleum Industry Press,2005.