INTELLIGENT OPTIMIZATION METHOD OF SCREW DRILL ASSEMBLY BASED ON BOREHOLE TRAJECTORY PREDICTION

by

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This study constructs an intelligent wellbore trajectory prediction and BHA optimization process, which ensures efficient optimization of the BHA on the premise of high wellbore trajectory prediction accuracy, the MAE of deviation and azimuth angles of the borehole trajectory model was 0.35° and 0.55°. The optimized BHA can effectively improve the deflection effect. It also has obvious advantages in calculation efficiency and can provide effective guidance and theoretical support for on-site BHA optimization.

Key words: *Wellbore trajectory prediction, BHA, screw drill assembly, intelligent optimization, sensitivity analysis*

Introduction

At present, wellbore trajectory control and deflection construction mainly rely on rotary steerable drilling tools and single-bend screws. The low cost of screw drill assembly makes it one of the most commonly used deflection bottom hole assembly (BHA). Therefore, how to analyze the deflection capabilities of single-bend screw drilling tools under different construction parameters, formation conditions, and parameters and optimize the screw drilling tool combination has become the key to controlling the wellbore trajectory.

In terms of BHA optimization design, the current mainstream design methods include usage effect analysis method, BHA mechanical model analysis method and knowledge engineering analysis method. The usage effect analysis method is to conduct statistical analysis based on the actual site effects. Dong *et al.* [1] used the modified three-point circle determination method to conduct preliminary design. Fan *et al.* [2] comprehensively considered the actual life of the drilling tools used on site, drilling speed and construction results. Analysis methods based on mechanical models include differential equation method, energy method, finite element method, longitudinal and transverse bending method. The earliest wellbore trajectory control model was based on the differential equation method. Walker and Friedman used the principle of minimum potential energy to establish the drilling tool assembly in the Mechanical analysis model under 3-D small deflection deformation [3]. The knowledge engineering analysis method conclude the representative products include Halliburton's Landmark drilling engineering software, Schlumberger's digital well construction software*, etc.*

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This study proposes a single-bend screw optimization method based intelligent algorithms. First, a well trajectory prediction model is constructed. Then, the drilling design parameters are input before or during the deflection operation. By coding the single-bend screw drill assembly and through the iteration of the optimization algorithm, a screw drill assembly parameter library that meets the on-site deflection requirements is selected to guide the site.

Theoretical background

Single-bend positive displacement motor drill-assembly

Single-bend positive displacement motor (PDM) drill-assembly is also called single-bend screw drill assembly, as shown in fig. 1.

Figure 1. Schematic diagram of single-bend screw drill tool assembly

Intelligent algorithms

– Random forest

The random forest algorithm is implemented based on ensemble learning and decision tree. It implement regression tasks by combining multiple decision trees, building multiple decision trees (regression tree) and combining them into a powerful regression model.

– Back propagation neural network

The back propagation network was proposed by Rinehart in 1986. It is a multi-layer feed forward network trained according to the error back propagation algorithm. It is one of the most widely used neural network models currently [4]. The topology structure of back propagation neural network model includes: Input layer, hidden layer and output layer.

– Genetic algorithm

Genetic algorithm is a classic optimization algorithm [5]. It simulates the replication, crossover and mutation that occur in natural selection and inheritance.

Methodology

Data preprocessing

This paper uses the 3σ outlier detection and linear padding methods commonly used in the field to process the logging data [6]. We use the minimum-maximum normalization method to normalize the data. Since the drill tool assembly parameter values are not continuous values. This study was coded through a continuous coding format, as shown in tab. 1.

Table 1. Screw drill assembly parameter coding

	Screw diameter [mm]	Bend angle [°]	Lower stabilizer diameter [mm]	Length between stabilizer and the bit [m]	Upper stabilizer diameter [mm]
Original data	120,135,172	1.0, 1.25, 1.5, 1.6,1.75	152, 160, 175, 190	0.4, 0.5, 0.6, 0.7	0, 155, 158, 185, 190
After coding	[0, 1, 2]	[0,1, 2, 3, 4, 5]	[0, 1, 2, 3]	[0, 1, 2, 3]	[0,1, 2, 3, 4]

Feature selection

Analyze the well logging data and mud logging data through spearman coefficient, select the parameters that have a greater correlation with the well deviation angle and azimuth angle, and filter out the parameters with poor timeliness. We select three well logging parameters and seven mud logging parameters. In addition, there are five screw drill assembly parameters. The model input and output are shown in tab. 2.

Table 2. The input and output parameters for the wellbore trajectory prediction model

Model parameters	Well logging	Mud logging	BHA
Input	Acoustic travel time deviation angle (last data point), azimuth angle (last data point)	Rate of penetration, rotary speed, weight on bit, total pump stroke, torque, flow out rate, well depth	Screw diameter, bend angle, lower stabilizer diameter, length between stabilizer and the bit, upper stabilizer diameter
Output	Deviation angle, azimuth angle		

Borehole trajectory prediction

We should first establish the relationship between the drill tool assembly, the formation, the deflection construction parameters and the deflection effect [7, 8]. The actual deflection effect on site is represented by the measured wellbore trajectory. The model evaluation indicators are given:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|(y_i - f(x_i))\right| \tag{1}$$

where N is the number of samples, y_i – the actual value, and $f(x_i)$ – the predicted value.

The back propagation neural network model still has certain advantages over the random forest model in the prediction of well deviation and azimuth angles. The MAE of the well deviation and azimuth angles are 0.35° and 0.55°, respectively.

Screw drill assembly optimization process

First, the deflection construction design parameters and the current well deviation angle and azimuth angle are input. The genetic algorithm continuously extracts the values of tool parameters from the range and inputs them into the model. The model gives the well trajectory at the next moment, and thus calculates the build-up rate. The overall optimization process is shown in fig. 2.

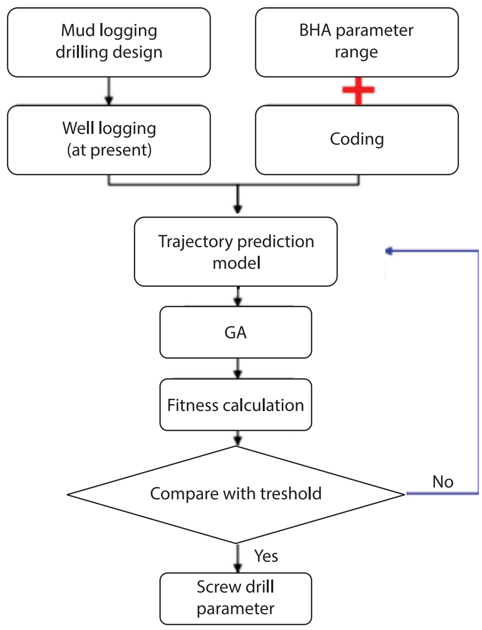

Figure 2. Screw drill assembly optimization process

The optimization steps of the genetic algorithm are mainly divided into seven steps:
- Step 1. Fitness threshold setting.
- Step 2. Chromosome coding.
- Step 3. Generate the initial population.
- Step 4. Fitness calculation.
- Step 5. Selection, crossover, and mutation form the next population.
- Step 6. Fitness is calculated until a threshold is met.
- Step 7. Decode to obtain the actual solution.

Experiment and results

Screw drill optimization experiment

The parameters of test well before optimization are: the depth of kick point is 800 m, inclination angle and azimuth angle of the build-up point are 9 and 22, respectively. Optimization starts with the maximum build-up rate as the target. The single-bend screw drill assembly parameters before and after optimization are shown in tab. 3. It can be seen that the maximum build-up rate has increased by more than 80%.

Table 3. single-bend screw drill tool assembly parameters optimization result

Status	Screw diameter [mm]	Bend angle [°]	Lower stabilizer diameter [mm]	Length between stabilizer and the bit [m]	Upper stabilizer diameter [mm]	K (Build-up rate) [° per 30 m]
Before optimization	135	1.25	152	0.4	155	4.74
After optimization	135	1.6	160	0.6	0	8.73

Analysis of experimental results

In order to verify the results before and after optimization, this study reproduced the build-up rate calculation mechanical model previously studied by some scholars, and conducted a single-factor sensitivity analysis. The results are shown in fig. 3.

The maximum build-up rate increases with the increase of the structural bend angle, we have the diameter of the lower stabilizer, and the distance between the drill bit and the stabilizer. The diameter of the lower stabilizer is generally larger than the outer diameter of the screw, which also results in the diameter of the screw drilling tool often being unable to show its mechanical properties during the build-up process. In addition, the diameter of the lower stabilizer is also related to wellbore cleaning calculations and needs to be comprehensively considered in [9, 10].

Conclusion

This study proposes a screw drill assembly optimization method based on wellbore trajectory prediction. First, back propagation neural network is used to construct a wellbore trajectory prediction model including formation parameters, construction parameters and drilling tool assembly. Then, by setting the construction parameters and current trajectory status, the genetic algorithm is used to continuously and iteratively generate a drill tool parameter combination, and optimization is carried out with the goal of build-up rate. The MAE of deviation and azimuth angles of the borehole trajectory model was 0.35° and 0.55°. The accuracy can meet the needs of field applications. In addition, the data-driven model can explore the impact

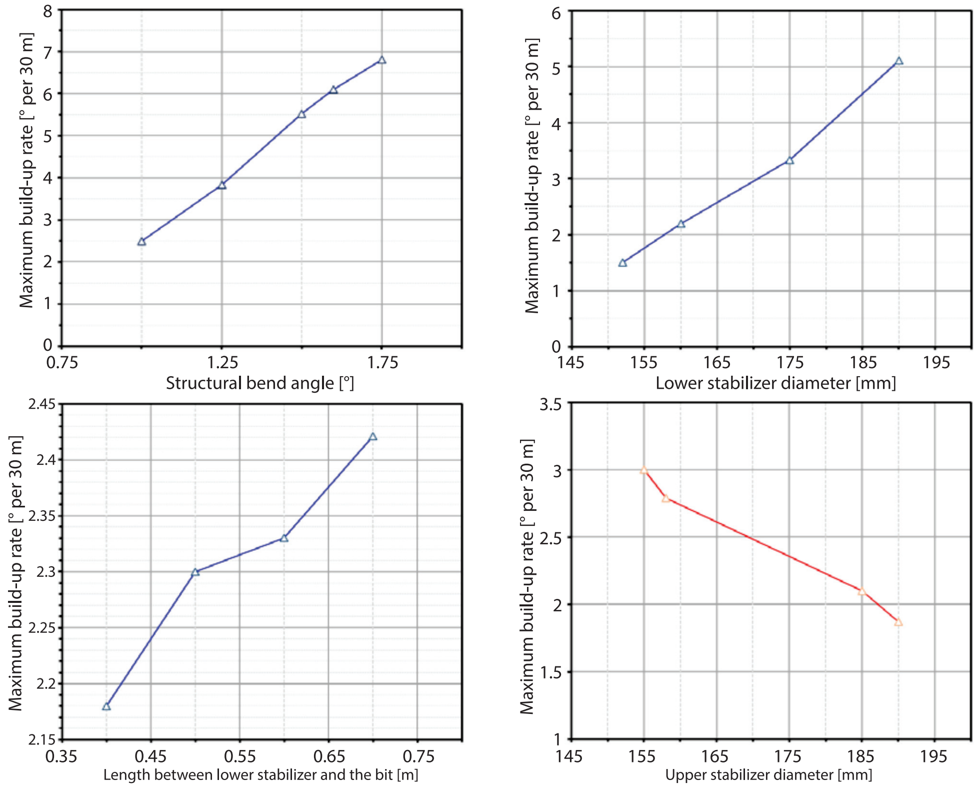

Figure 3. The sensitivity analysis for the single-bend screw drill assembly parameter

of some potential parameters on slope construction. Compared with the mechanical model, its considerations are scalable and more comprehensive. The genetic algorithm can optimize multiple parameters at the same time. Compared with traditional sensitivity analysis and orthogonal experiments, it is more efficient and can effectively explore the coupling effects of multiple parameters on the deflection process.

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