Applied Ocean Research 48 (2014) 301–307

Contents lists available at ScienceDirect

Applied Ocean Research

journal homepage: www.elsevier.com/locate/apor

Methods of setting depth range with credibility of conductor for deepwater drilling based on probability statistics

Yuqiang Xu [a,*], Zhichuan Guan [a], Kanhua Su [b]

[a] Department of Petroleum Engineering, China University of Petroleum (East China), 266580 Qingdao, China
[b] Chongqing University of Science and Technology, 401331 Chongqing, China

ARTICLE INFO

Article history:
Received 29 January 2014
Received in revised form 30 May 2014
Accepted 24 October 2014
Available online 15 November 2014

Keywords:
Probability statistics
Deepwater drilling
Setting depth of conductor
Credibility

ABSTRACT

Becasuse of the deep water depth and long riser of deepwater drilling, the stability of subsea wellhead is threatened. Meanwhile, the setting depth of conductor directly affects the mechanical stability of subsea wellhead. Through analyzing the impact of different factors on the setting depth of conductor, we found that the bearing capacity growth factor of subsea soil has a great influence on the setting depth of conductor. However, the coefficient is a regional and empirical constant, which seriously affects the accuracy and reliability of the results. In this paper, probability statistics and geostatistics methods are employed to count the bearing capacity growth factor of target point's adjacent wells, as well as transplant and predict the target point through differential arithmetic, which can obtain the predictive value of target point's coefficient containing probability information. Finally, we can obtain the setting depth range with credibility of conductor. This is conducive to designers to calculate the setting depth of conductor with other uncertain factors taken into account, and reasonably control the potential risks.

1. Introduction

The biggest difference between deepwater drilling and shallow drilling or land drilling is the water depth, which requires a long riser to ensure the drilling operations [1–3]. Affected by the drilling vessel drifting and sea current beating and other issues, the riser would threaten the stability of subsea wellhead mechanics [4–7]. Recent years scholars have conducted relational studies such as riser stress state, the stability of subsea wellheads, the bearing capacity of casing string below the mud line, the setting depth of conductor and so on, they have drawn some valuable conclusions [8–10]. Among them, the setting depth of conductor in deepwater drilling directly affects the mechanical stability of subsea wellhead. If the depth design is relatively shallower, it will lead to instability of subsea wellhead; on the contrary, if the design depth is deeper, although it can ensure the security of subsea wellhead, it will result in a waste of resources, and may cause the conductor can not be to the specified depth [15–17]. Through investigation of currently used methods of setting depth of conductor for deepwater drilling [9–12], we found that the calculated value is a single value, while there are many uncertainties in the parameters of subsea shallow strata in deepwater drilling. So it is essential to analyze the reliability of the results.

Based on probability statistics and geostatistics methods [12,20], we can count the regional stratigraphic parameters which is uncertain or difficult to determine, and predict the target point's relevant parameters containing probability information through differential arithmetic. If this idea is introduced into the calculation of setting depth of conductor for deepwater drilling, firstly, count the regional stratigraphic parameters which is uncertain or difficult to determine; secondly, transplant and predict the target point through differential arithmetic, which can obtain the predictive value of target point's relevant parameters containing probability information; lastly, use the conventional method to calculate the setting depth of conductor, we finally obtain a value range with credibility. Compared with the previous single value, each value within the range corresponds to a certain probability, and the value range has a certain credibility, which is bound to provide more effective guidance for the setting depth of conductor in deepwater drilling, and has significance for the rational depth design, avoiding the potential risks and controlling risks, etc.

2. Materials and methods

2.1. Conventional methods for determining the setting depth of conductor in deepwater drilling

Currently, hydraulic jet is generally used to run in conductor of deepwater drilling to reduce expensive deepwater drilling day rate for saving time. The conductor only provide structural support

* Corresponding author. Tel.: +86 13165151114.
E-mail address: auyuqiang@163.com (Y. Xu).

0141-1187/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.apor.2014.10.007

but can't withstand the pressure, and its setting depth is generally 30–120 m, which mainly depends on the ability of subsea shallow soft soil to support the conductor and subsequent casing string. If the depth of conductor is too shallow, it will lead to instability of subsea wellhead; on the contrary, if the depth is too deep, although it can ensure the security of subsea wellhead, it will result in resource waste, even may cause the conductor cannot run to the specified depth.

2.1.1. Calculation of the bearing capacity of conductor in deepwater drilling

To determine the setting depth of conductor is inseparable from the force conditions of hydraulic jet process, and the bearing capacity of conductor will be affected by time effect. Currently, the calculation methods for bearing capacity of conductor in deepwater drilling, which take more comprehensive factors into account and have more accurate results are as follows [10]:

(1) The initial bearing capacity of conductor:

$$Q_0 = R \cdot B_{fw} \cdot [(W_{con} + W_{col}) \cdot x + W_{lh} + W_{tool}] \tag{1}$$

where Q_0 is the initial bearing capacity of conductor (kN); R is bit weight exponent, 0.8 to 1.0; B_{fw} is the buoyancy coefficient in seawater; x is designed length of conductor (m); W_{con} is the unit length gravity of conductor (kN/m); W_{col} is the unit length gravity of jet drilling tools (kN/m); W_{lh} is the gravity of low-pressure wellhead (kN); W_{tool} is the gravity of running tool (kN).

(2) The bearing capacity of conductor after running to the specified depth and hanging surface casing:

$$Q_w = B_{fd} \cdot (W_{con} \cdot x + W_{scr} \cdot L_{sc}) + B_{fw} \cdot (W_{lh} + W_{hh}) \tag{2}$$

where Q_w is the bearing capacity of conductor after running to the specified depth and hanging surface casing (kN); B_{fd} is the buoyancy coefficient in drilling fluid; W_{scr} is the unit length gravity of surface casing (kN/m); L_{sc} is the setting depth of surface casing (m); W_{hh} is the gravity of high-pressure wellhead (kN).

(3) The ultimate bearing capacity of conductor:

$$Q_u = \pi D_c \sum_{i=0}^{x} q_{sui} L_i + \frac{\pi}{4}(D_c^2 - d_c^2) q_{pu} \tag{3}$$

where Q_u is the ultimate bearing capacity of conductor (kN); D_c is the conductor outer diameter (m); d_c is the conductor inner diameter (m); q_{sui} is the limit side resistance per unit area of i-layer of soil around the conductor (kPa); q_{pu} is the limit tip resistance per unit area (kPa); L_i is the thickness of the i-layer soil (m); x is the number of soil stratification.

(4) The real-time bearing capacity of conductor:

$$Q_t = Q_0 + \alpha_b(1 + \log t)(Q_u - Q_0) \tag{4}$$

where α_b is the bearing capacity growth factor; t is the recovery time (d).

Integrate formulas (1), (3) and (4), we can have the real-time bearing capacity of conductor after a certain recovery time:

$$\begin{aligned} Q_t = {} & B_{fw} \cdot [(W_{con} + W_{col}) \cdot x + W_{lh} + W_{tool}] \\ & + \alpha_b(1 + \log t)\left\{ \pi D_c \sum_{i=0}^{x} q_{sui} L_i + \frac{\pi}{4}(D_c^2 - d_c^2) q_{pu} \right. \\ & \left. - B_{fw} \cdot [(W_{con} + W_{col}) \cdot x + W_{lh} + W_{tool}] \right\} \end{aligned} \tag{5}$$

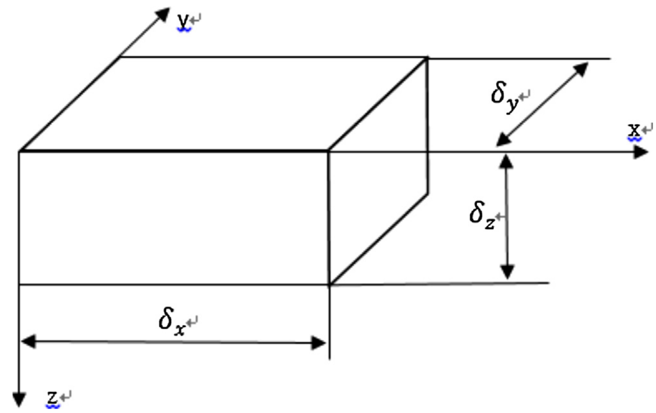

Fig. 1. Schematic diagram of regional meshing.

2.1.2. Methods for determining the setting depth of conductor

In order to ensure the reasonableness of the setting depth of conductor, it needs to make design criteria for the setting depth of conductor in deepwater drilling:

$$\varepsilon_d < Q_t - Q_w < \varepsilon_u \tag{6}$$

where ε_d is the lower limit of reasonable margin of safety (kN); ε_u is the upper limit of reasonable margin of safety (kN); Q_w is the total load of conductor (kN).

Based on the above criteria, we can use the iterative method to check for the real-time bearing capacity of conductor when t time and the total load of conductor, and ultimately determine a reasonable setting depth of conductor.

2.2. Methods for regional prediction of formation parameters

Drilling design process needs to use a variety of formation parameters, some of which are difficult to actually monitor, and this is more prominent in deepwater drilling. If these formation parameters in a region have the characteristics of space limitations, continuity and anisotropy, etc. at the same time, we can identify that they are regional variables, so that we can use geostatistical theory to predict its regional value [13,14].

First, mesh the region, and use square grid as shown in Fig. 1. Wherein, δ_x and δ_y are reasonable values based on the size and number of data points in the region, and try to ensure that each grid contains at least one data point. δ_z is the thickness of the grid, if the formation parameters vary in the longitudinal direction, make a reasonable value according to the thickness of the stratum to ensure accuracy; If this parameter is unchanged in the longitudinal direction, we can make $\delta_z = 0$, namely planar mesh.

Assuming that the space expression of the regional stratigraphic parameter is $\alpha_i(x_i, y_i, z)$, where i is the number of known data points.

(1) If the formation parameters vary in the longitudinal direction, the value of formation parameter for each grid is

$$\beta_i(x_i, y_i, z_k) = \frac{1}{m} \sum_{i=1}^{m} \frac{1}{z_{k+1} - z_k} \int_{z_k}^{z_{k+1}} \alpha_i(x_i, y_i, z)\, dz \qquad k = 0, 1, 2, \ldots, n \tag{7}$$

where m is the number of data points in the grid.

(2) If the parameter is unchanged in the longitudinal direction, the value of formation parameter for each grid is

$$\beta_i(x_i, y_i) = \frac{1}{m} \sum_{i=1}^{m} \alpha_i(x_i, y_i) \tag{8}$$