The mechanical model of the large angle well with the layered water injection pipe column and force tester

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Abstract

Based on the theory and technology of pipe string mechanics, computer simulation, mechanical and electrical integration, the mechanical analysis model of the large angle well is established and Researched on simulation software. In order to verify the accuracy of the theoretical analysis and the axial force of the pipe string, And control the axial force of underground pipe string, the load test device of the high angle well is designed. At the same time ,carrying out high angle wells water injection string stress test of down hole instrument test, according to test results, improving the high angle wells water injection string mechanical model, so a complete set of high angle wells tube column stress formation analysis system is formed .The test results show that the error of the calculation of the pulling force on the pipe string is basically within 5%, and the individual well exceeds 5%, but it is also within 10%.

Keywords

high angle well, stratified water injection, water injection pipe string, the force measuring instrument..

1. Introduction

Nanbao oil field belongs to the offshore oilfield, is restricted by the ground and underground conditions, Multi use directional well and horizontal well mining, which The majority of the injection wells are highly deviated directional wells. Nanbao oil field development is far from the artificial island, the jacket wellhead position is more and more far, the displacement, inclination more are more and more large , according to statistics for injection wells deviation is more than 40 degrees, horizontal displacement reaches 3km, Part has reached 4km. The water injection wells in the Nanbao oil field are characterized by high angle of the building, large angle of the well, long horizontal section and the large slope of the Injection section. The mechanical conditions of the layered water injection pipe string in the well are more complicated. Under the effect of multi well and high angle deviated, enhance the sensitive of the friction resistance of the tube column, decentralization process prone to lowering pipe column does not reach the designated position, Pipe string difficulties, etc; pipe string in seating and sealing, water injection and the back flushing of wells and other conditions, by the force condition difference is larger, leading to the deformation, creep is more complex and intense. Therefore, in the process of operation, the permanent helical buckling, plastic failure, failure and failure of the packer, the early failure of the pipe string and the early failure of the pipe string are becoming more and more prominent. It seriously affects the development level of the oil field water injection, which directly affects the normal production and economic benefits of the oil field [1-2].1 axis force model of the mechanical model of the water column in the high angle well

Water injection pipe column is according to the requirements of the water injection process consists of an elongated flexible pipe column, a water distribution device, sealing packer, a ball seat, and a anchoring tool. In the process of operation, the pipe string can be influenced by the weight of the tube, the friction between the tube and the wall, the viscous friction of the fluid inside and outside the tube, the buoyancy of the fluid in the wellbore, the internal and external pressure. Therefore, in the stress analysis must be fully considered. There are different characteristics in the different section of the high angle deviated well, the well deviation angle and the azimuth angle. Therefore, it is necessary to consider the characteristics of the well trajectory.

In order to comprehensive analysis of various factors on the tube column mechanics behavior and properties, using infinitesimal method is established based on the actual well trajectory 3D high angle injection well pipe string mechanical model [3]. At the same time, taking into account differences in highly deviated wells in each interval of hole deviation and hole curvature using basic idea of "rigid rod" and "soft rope” model, high angle deviated well water injection string 3D rigid rod mechanical model and the three-dimensional soft rope mechanical model were established.

1.1 Basic hypotheses

In order to facilitate the establishment of mechanical model, it is necessary to simplify the stress conditions of the pipe string. The basic assumption of the following: (1) the shaft wall is rigid, and the rigidity of the pipe string is considered; (2) The pipe string is in continuous contact with the wall, and the axis of the tube is consistent with the shaft of the borehole.; (3) the calculation of the curved tube column element is a section of a circular arc on the space plane.

1.2 The establishment of three-dimensional mechanical model of rigid rod model

In the increasing of inclined section pipe column is curved wellbore bound, it Will produce additional bending moment, and increase the friction of the tube column, so will establish consider pipe stiffness of 3D rigid rod "mechanical model is used to describe highly deviated well curved segment of the well pipe column stress [9].

In accordance with the Frenet formula describes the trajectory method, in the tube along the axis of the column to get the natural coordinate system O_sTNB and in the tube column from any arc length ds element AB as the stress analysis of the object, as shown in Figure 1. Taking the point A as the starting point, the curvilinear coordinates are S , the point B is the end point, and the curve coordinates are $S+ds$. Considering the influence of each segment of the load, the concentration and the moment, and the stress analysis is carried out.

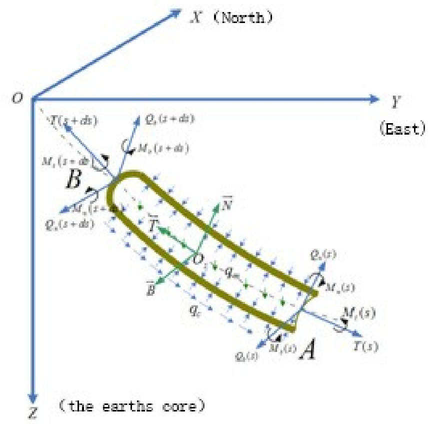


Figure 1 Infinitesimal force diagram

Due to the infinitesimal section where the borehole axis adjacent measuring two points for space on the inclined plane of a circular arc, so wellbore deflection rate is always face closely, by the osculating plane definition shows that $\tau = 0$, through the analysis of force can establish force and moment equilibrium equation , combined with the column physics equation ,The mechanical model of the rigid rod of the inclined section can be obtained:

$$\begin{cases} \dfrac{dT_t - dP_i A_i + dP_o A_o}{ds} + K \cdot EI \dfrac{dK}{ds} \pm \mu_\alpha N + f_\lambda - q_m \cos\alpha = 0 \\ \dfrac{dM_t}{ds} = \mu_t RN + 2\pi R^3 \omega \left[\dfrac{\tau_f}{\sqrt{v^2 + (R\omega)^2}} + \dfrac{2\mu}{D_w - 2R} \right] \\ -EI \dfrac{d^2 K}{ds^2} + K \cdot T + N_n + \mu_t N_b + q_m \sin\alpha \dfrac{K_\alpha}{K} = 0 \\ -K \dfrac{dM_t}{ds} + \mu_t N_n - N_b - q_m \sin^2\alpha \dfrac{K_\varphi}{K} = 0 \\ N^2 = N_n^2 + N_b^2 \end{cases} \tag{1-1}$$

In the formula, K_f-the buoyancy factor, $K_f = 1-\rho_m/\rho_s$ (ρ_m for the wellbore fluid density, ρ_s the material density of the tubing); q-the unit weight of the tube column in the air, KN/m. N_n positive pressure of Ptincipal normal direction, KN; N_b - positive pressure of the binormal direction, KN; μ_t -Friction coefficient of circumferential direction; μ_α - Friction coefficient of axis direction. A_i-Tubing lumen cross-sectional area, m^2; P_i-Tubing internal pressure,. A_o-Tubing lumen cross-sectional area, m^2; P_o-Tubing internal pressure Mpa,. τ_f Fluid structure force; N/m; μ -fluid dynamic viscosity Ns/m^2, ω the rotating angular velocity of the tube rad/s, D_w the hole diameter m, R the outer radius of the tube m, v the fluid velocity m/s.

1.3 The establishment of three-dimensional mechanical model of the soft rope

In the straight, steady wells, tube stiffness and borehole curvature on the impact force of column is relatively small, Pipe string in the well will not be affected by bending moment and shear force. Therefore, the use of the basic ideas of "soft rope" model, A soft rope mechanical injection pipe column three-dimensional wellbore analysis model.

In building models, according to the characteristics of the soft rope model, based on the above assumptions, further simplifying assumptions: (1) without considering the pipe stiffness influence on stress, not considering the bending moment in the borehole; (2) ignore columns on shear.

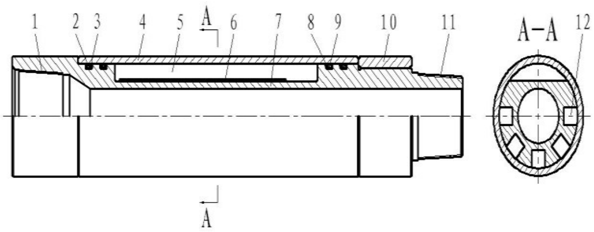
Use the same infinitesimal method carries on the stress analysis of tube column, it can be established by the force balance equations. Therefore, the mechanical analysis model of pipe string "soft rope" can be established:

$$\begin{cases} \dfrac{dT_t - dP_iA_i + dP_oA_o}{ds} \pm \mu_\alpha N + f_\lambda - q_m \cos\alpha = 0 \\ \dfrac{dM_t}{ds} = \mu_t RN + 2\pi R^3 \omega \left[\dfrac{\tau_f}{\sqrt{v^2 + (R\omega)^2}} + \dfrac{2\mu}{D_w - 2R} \right] \\ K \cdot T + N_n + \mu_t N_b + q_m \sin\alpha \dfrac{k_\alpha}{k} = 0 \\ -K \dfrac{dM_t}{ds} + \mu_t N_n - N_b - q_m \sin^2\alpha \dfrac{K_\varphi}{k} = 0 \\ N^2 = N_n^2 + N_b^2 \end{cases} \tag{1-2}$$

2. Development of force measuring instrument

The test instrument is composed of sensor, data acquisition circuit board, power supply module and force test of joint.

2.1 mechanical structure design of the force measuring instrument



1 - short internal thread joint; 2, 9 - O shaped seal ring; 3, 8 - sealing rings; 4-outer cylinder; 5 - electronic equipment cabin; 6 - data acquisition board; 7 - tube; 10 - end of the baffle; 11 - short external thread joint; 12 - battery groove.

Figure 2 Schematic diagram of force test joint structure

According to technology design parameter and layout of the load test short, combined with the high angle deviated wells down hole structure characteristics, construction requirements and the contour size of electronic components ,referring to down hole tools and experience design of instruments and sensor design specification, The mechanical structure design of high angle well injection pipe column short load test. [4-6].

2.2 test principle and system design of the force measuring instrument

test principle of the stress tester. The stress tester uses the method of the whole bridge to measure the arm, the longitudinal strain gauge is used as the strain measurement, the lateral strain gage is used as the temperature compensation, and the bending and temperature effects are eliminated. Because the load tester is placed in the high angle well water injection pipe column near the end of the packer, In theory, it is mainly caused by the axial tension stress, such as the weight of the pipe, the pressure difference between inside and outside the column, floating weight effect, the effect of temperature and friction effect, Without considering the bending moment and torque. Therefore, the test system of the axial tension force sensor with temperature compensation function of resistance strain gauge measurement, the strain gauge is attached to a specific region of the circular groove of the strain cylinder, in order to eliminate the possible bending moment, force and other factors caused by the bending of additional factors . [7-8]

According to the measurement principle of the axial tension strain, the strain in the axial direction is the largest, and the symmetrical patch method along the axial direction is used as the temperature compensation. The placement method and the way of the concrete strain gauges are shown in Figure 3 and Figure 4.

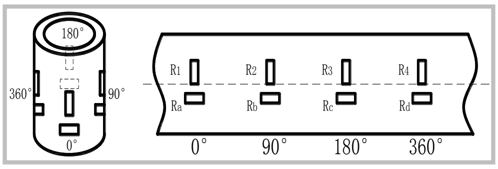


Figure 3 Schematic diagram of pasting strain gauge

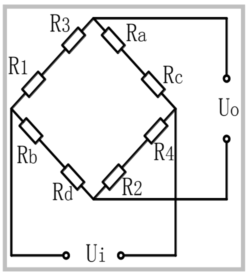


Figure 4 strain gauge measuring method of bridge

$$\begin{cases} \varepsilon_1 = \varepsilon_N + \varepsilon_w + \varepsilon_t \\ \varepsilon_2 = \varepsilon_t \\ \varepsilon_3 = \varepsilon_N - \varepsilon_w + \varepsilon_t \\ \varepsilon_4 = \varepsilon_t \end{cases} \Rightarrow$$

$$\begin{cases} \varepsilon_{ds} = \varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4 \\ = (\varepsilon_N + \varepsilon_w + \varepsilon_t) - \varepsilon_t + (\varepsilon_N - \varepsilon_w + \varepsilon_t) - \varepsilon_t \\ = 2\varepsilon_N \end{cases} \quad (2\text{-}1)$$

In the formula, ε_N the strain caused by the bending moment, ε_w the strain caused by the axial force, ε_t the strain caused by the temperature change.

Design of stress test system. The stress testing system must have the function of complete signal conditioning, data acquisition, storage and reading, and the electronic components should have good high temperature stability.

The stress testing system mainly includes two parts: hardware and software.

hardware: including resistance strain gauge, data acquisition circuit board, signal conditioning module, high temperature lithium battery and other electronic components. Software: including data acquisition and storage management procedures, PC data export analysis software, etc.

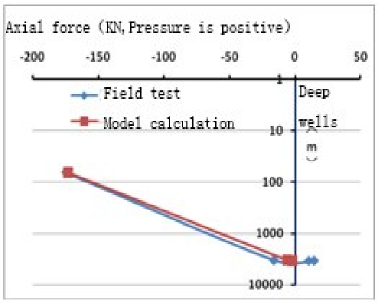
3. Instance verification

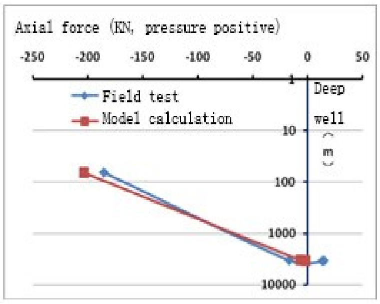
In the field of the test, the stress test of the 1 well was carried out with the test apparatus, and compared with the mechanical model. Well parameters see Table 1.

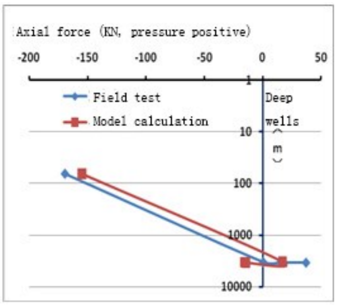
Table 1 The basic parameters of the three section of NP23-2608 well

Calculation parameters	Backwashing calculation time	30min	Pipe string parameter	ZJM-110 anchor card solution step by step	3307.3m
	Water flooding	10min		JDY341-110 packer 1	3317.15m
	Backwashing displacement	270L/MIN		JDY341-110 packer 2	3358.18m
	Water injection displacement	280L/min		JDY341-110 packer 3	3389.86m
	Surface temperature	22		Fixed ball seat	3420.57m
	Fluid temperature	22.8		Plug	3421.73m
	Water injection pressure	9		ZJM-110 by solution of anchor card releasing force	152.2KN
	Backwashing pressure	1		JDY341-110 packer 1 releasing force	24.9KN
	Density	1070		JDY341-110 packer 2 releasing force	22.4KN
	Maximum wellhead pressure	20Mpa		JDY341-110 packer 3 releasing force	8.3KN
	Seat seal pressure	15Mpa		Force tester 1 position	64.49
	Friction coefficient	0.15		Force tester 2 position	3306.45
				Force tester 3 position	3357.68
				Force tester 4 position	3389.35

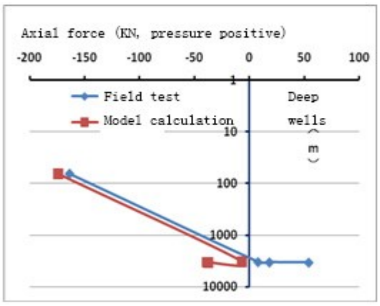
The results of field tests and model calculations are shown in the following diagram.

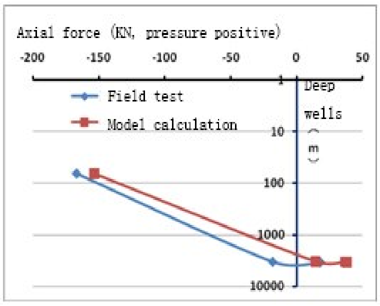


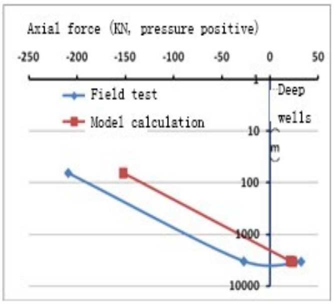




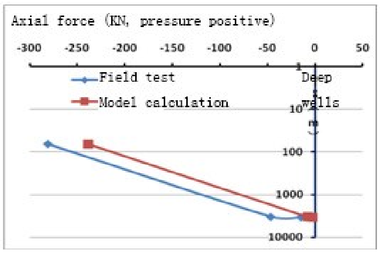
Lower pipe working condition Static state Seat seal (15MPa)







Seat seal (20MPa) Water flooding After backwashing water injection



Pull up tube

From the results above can be drawn from the pipe column error in less than 10%; sitting seal pressure from 15MPa-20MPa, string stress decreases gradually, reflect the test and calculation is consistent; upper tubular column can be appropriate to increase the test short.

4. Conclusions

On the basis of a large number of domestic and foreign literature research and field survey, the mechanical analysis model of the large angle well water injection pipe string is established based on the analysis of the influence of the hole trajectory, friction force, viscous friction, pipe string gravity, buoyancy, internal and external pressure and so on; The mechanical analysis model of the large angle well water injection pipe string was established by using the three-dimensional "rigid rod" and "soft rope".

Through field application test shows that the system is stable and reliable in high temperature and high pressure environment. and the performance meets the design requirements. Because of the complex environment of high angle wells, so it is necessary to improve and optimize the load test system. At the same time, the field test value is compared with the theoretical calculation of water injection pipe column.

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