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Research Article

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Mechanical analysis of separate layer water injection tubular column

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ABSTRACT

This article makes a comprehensive study of the various effects of separate layer water injection tubular column in the wellbore. On this basis, a mechanical analysis model of the packer is established, In the model, we consider that different tools such as anchoring tools，length accumulators have an effect on the force of packer, and we establish a packer force model, which is much closer to the actual operating conditions, to provide a more practical value for water injection string performance evaluation, construction parameter optimization and design of water injection string.

Keywords: Separate Layer Water Injection, Packer, Mechanical Model, Simulation Analysis

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INTRODUCTION

With the gradual development of the mid-late period of oilfield, oil and gas exploration and development are developed to the high temperature, high pressure and complex deep formation, and the use of various of unconventional well, make the force situation of separate layer water injection tubular column are extremely complex[1]. The injection pressure and the interlayer pressure difference gradually increase，operating conditions trend to be diversified and complex, the problems of tubular column security and packer creep failure become increasingly prominent. The cur-rent theoretical modeling to consider various factors is not comprehensive enough, the pressure is only still a major consideration in the analysis of complex conditional well[2].

As a result, based on the existing research, we establish a logical mechanical model of tubular column, comprehensively consider effects of friction, internal and external pressure, viscous friction, deviation angle and crooked-hole tendency and other factors, make more comprehensive analysis of the various effects that water injection tubular column in the wellbore subjected, and a mechanical analysis model of the packer is established[3]. At the same time, the packer anchor position depends not only on the friction of its own, in most cases is also equipped with the corresponding tools, such as anchoring tools，length accumulators, etc. These tools also have great effect on the force situation of the packer, for all kinds of tools in modeling will be taken into account, so that it is closer to the actual conditions of the mechanical model, more reasonable and prepare a corresponding simulation program based on this, to provide a more practical value for water injection string performance evaluation, construction parameter optimization and design of water injection string.

EXPERIMENTAL SECTION

Base on the comprehensive consideration of the well trajectory, friction, viscous friction, column weight, buoyancy force and other factors, regard wellbore temperature field as data source of temperature effect to solve thermal deformation; the pressure is calculated as the known data, input to the tubular column mechanics software to solve the deformation of the tubular column. According to the actual situation of injection operations, axial mechanical analysis model is established by using micro-element method based on the measured trajectory three-dimensional curved of the water injection column, and nonlinear equations of quasi-Newton iterative method is used to solve the model[4,5].

2.1 WATER INJECTION COLUMN AXIAL LOAD MECHANICAL MODEL BASED ON THE MEASURED THREE-DIMENSIONAL TRAJECTORY BOREHOLE

Axial load analysis is an important part of Column mechanical behavior study, and three-dimensional curved wells trajectory is more complicated. In the three-dimensional curved wells, column axial load is generated by the column, column and wall friction, viscous friction of the fluid injected into the buoyancy of the liquid, the pressure inside and outside the column, the column bending and dynamic load, etc. Water column axial load mechanical model based on the measured three-dimensional trajectory borehole was established to describe the whole string along the depth direction of the axial load distribution reasonably which has great significance in the master and control of various parts of the column mechanical state.

2.1.1 BASIC ASSUMPTIONS

(1)Contact of shaft lining and tubular column is rigid, taking rigid column into consideration.
(2) Contact of shaft lining and column is continuous, the column axis and the axis of the borehole is consistent.
(3) Gravity, positive pressure, friction resistance of column unit are evenly distributed;
(4) Unit body of bent column calculated is an equal curvature arc in space oblique plane.
(5) Without considering the influence of dynamic load in pulling column.

Taking natural coordinates, because it has been assumed that the column is fully restricted wellbore, the wellbore center line and the center line of the column have the same trajectory. In borehole office take a curvilinear coordinate the infinitesimal arc length ds body, and its stress analysis to point A is the starting point, the curve coordinates s, B point to the end point, the coordinates of the curve, force of this micro-segment shown in Fig. 1.

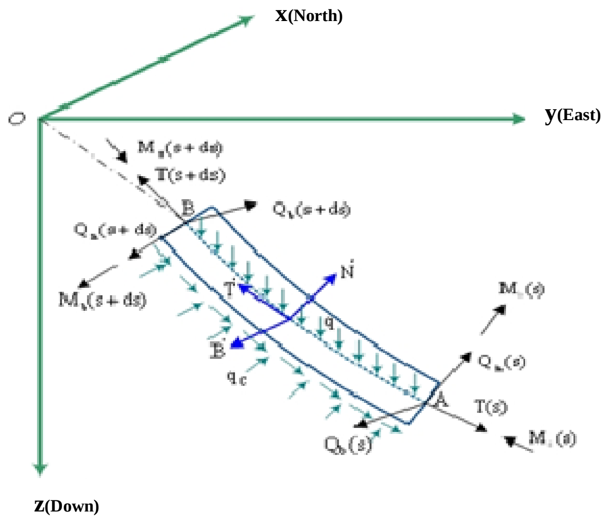


Figure 1. Free body diagram of infinitesimal section

2.1.3 Equation Establishing

Injection string axial load model, with well trajectory, column weight, friction within the wall of the column and the column, external fluid pressure, viscous drag effects considered, can be obtained from geometric equations, equilibrium equations, physical equations and boundary conditions of modeling

$$\begin{cases} \dfrac{dT_e(s)}{ds} = -kEI\dfrac{dk}{ds} - \mu_\alpha N - f_\lambda + (q_m + \rho_i g A_i - \rho_o g A_o)\cos\alpha \\ k\dfrac{dM_t}{ds} = -M_t\dfrac{dk}{ds} + \tau EI\dfrac{dk}{ds} + N_b - \mu_t N_n + (q_m + \rho_i g A_i - \rho_o g A_o)\dfrac{k_\phi}{k}\sin^2\alpha \\ \dfrac{dM_t(s)}{ds} + \mu_t RN + 2\pi R^3\omega\left[\dfrac{\tau_f}{\sqrt{v^2 + (R\omega)^2}} + \dfrac{2\mu}{D_w - 2R}\right] = 0 \\ EI\dfrac{d^2k}{ds^2} = kT(s) - N_n - \mu_t N_b + (q_m + \rho_i g A_i - \rho_o g A_o)\dfrac{k_\alpha}{k}\sin\alpha \\ N^2 = N_n^2 + N_b^2 \end{cases}$$

In these equations,

M_t —Torque, kN·m;

N —Positive contact pressure with shaft lining, kN;

N_n —Contact pressure with shaft lining in major normal line direction, kN;

N_b — Contact pressure with shaft lining in side normal line direction, kN;

μ_a —Axial friction coefficient;

μ_t — Circumferential friction coefficient.

2.2 Temperature field model

Before the injection and production, the temperature of the tubing string in the wellbore is almost the same to formation. However, after the start of injection and production, there have been some liquid pulling into the wellbore from ground, breaking the heat balance of the original wellbore, the tubing string temperature changes with the injection fluid constantly. For the original wellbore temperature field calculation is according to geothermal gradient model ($T_{dz} = T_m + \alpha \cdot z$) to solve, without considering the impact of thermal conductivity water injected. We are considering the wellbore heat conduction and convection to establish wellbore temperature field model, solving the exact value of the wellbore temperature change during the mass transfer column, using these as the temperature effect data sources to calculate the deformation amount generated by temperature effects When solving unstable temperature field, the format of difference in time to promote can use following categories: forward difference scheme, backward difference scheme, Crank-Nicolon format, Galerkin format.

Forward difference format is explicit difference method and the other three are implicit difference methods. Forward difference scheme does not have to solve algebraic equations, but has a poor stability. Forward and backward difference scheme's solving accuracy is low.

This article is calculated using the following formula:

$$\frac{T_{k+1} - T_k}{\Delta t} = \frac{\partial T_k}{\partial t} + \theta \cdot \left(\frac{\partial T_{k+1}}{\partial t} - \frac{\partial T_k}{\partial t}\right) \quad , \quad (0 \le \theta \le 1)$$

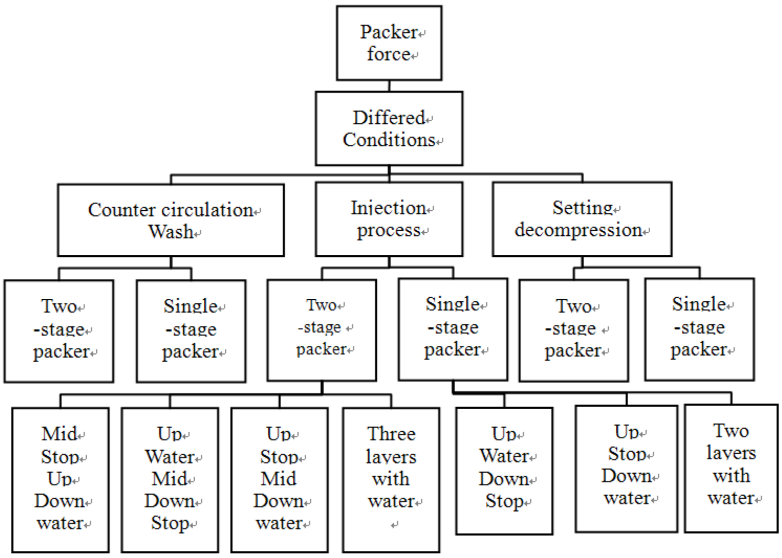
The temperature field calculation program, the user can select a value, determine the time difference advancing formats, such as:

$\theta = 0$: Forward difference scheme;
$\theta = 1$: Backward difference scheme;
$\theta = 0.5$: Crank-Nicolon format;
$\theta = 2/3$: Galerkin format.

The latter two difference schemes are better in the four difference schemes above, because the Crank-Nicolon format treats the time advance for linearization; Galerkin format treats for parabola. It is closer to the actual situation, and can get higher accuracy and better stability.

III. DEFORMATION ANALYSIS IN DIFFERENT CONDITIONS

Considering the water column of the combined effects of a variety of factors, an axial deformation of different ways of injecting the column model in three kinds of conditions, six kinds of string type, was established.



The effects of different construction process parameters, packer peristaltic displacement, deformation of the pipe string variable and packer force were researched.

For example, the packer string process deformation is:

$$\Delta L_{坐} = -\frac{L\times 10^{-3}}{\mathrm{E}A}\left[\left(A_P - A_i\right)\Delta P_i - \left(A_P - A_o\right)\Delta P_o\right] - \frac{2\mu\left(\Delta P_i d^2 - \Delta P_o D^2\right)}{E(D^2 - d^2)}L + \alpha L \Delta T$$

The column operation shift is as follows:

$$\Delta L_{注} = -\frac{L\times 10^{-3}}{\mathrm{E}A}\left[\left(A_P - A_i\right)\Delta P_i - \left(A_P - A_o\right)\Delta P_o\right] - \frac{2\mu\left(\Delta P_i d^2 - \Delta P_o D^2\right)}{E(D^2 - d^2)}L + \frac{F_f r^2}{4EI}L_e + \alpha L \Delta T + \frac{2\lambda\rho_0 v^2 dL^2}{E\left(D^2 - d^2\right)}$$

By packer stress analysis under different conditions, it has provided a theoretical basis for further optimization of the column structure and improvement of the packer stress state.

CASE STUDY AND DISCUSSION

On the basis of these studies, we designed the packer stress analysis simulation program. In the program, the database of injection tools types was added. Appropriate performance characteristics packer force model can be established according to a variety of tools, such as the calculation of: anchoring tools, compensation tools to calculate the forces of packer in different conditions and determines whether the packer creep occurs. On this basis of two injection wells' actual operating conditions in Shengli Oilfield, packer simulation was done under different hydraulic injection conditions.

4.1 Examples of a temperature field calculation

Fig. 2 shows a specific configuration of the column, tubing type is 2 7/8 TBG, shaft lining thickness is 7.82mm. The injection wells used "plugging above and injecting below" water craft.

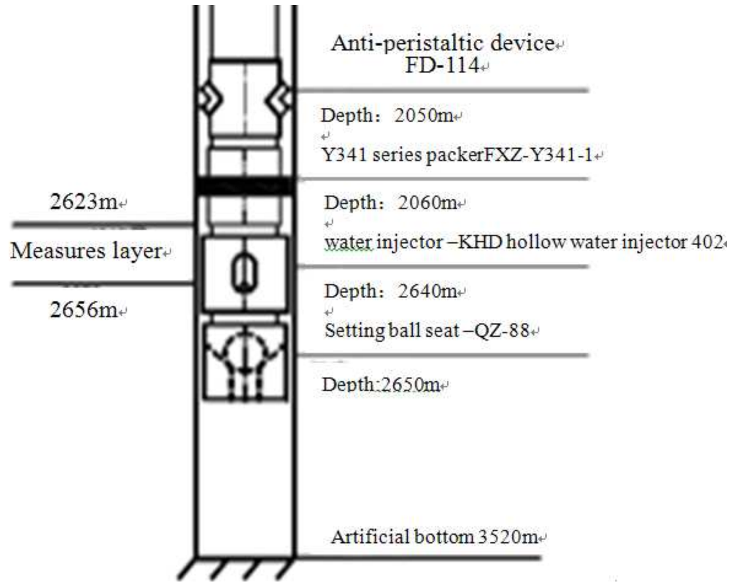


Figure 2. Column Structure

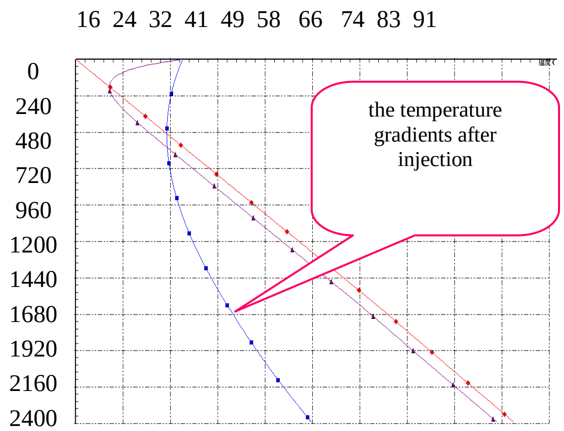


Figure 3. software calculations

By contrast with the results calculated by the software and field test results, the temperature gradients after injection are very close. The temperature field model is in line with the actual field, the effect of temperature on the column calculated by the software can also be consistent with the actual.

Table 1 field measurement temperature

Depth（m）	Temperature(℃）
200	31.2
400	31
600	31.3
800	32
1000	33.3
1200	35
1400	37
1600	39.3
1800	41.9
2000	45.1
2200	48.4
2400	51.9
2600	55.6

4.2 Second example (String force deformation calculation)

DXY17-41 well completion string is at right, supporting the BCQ-114FY compensator, CX-402FY, 403 water distribution, Y341-113GFY compression packer and PH-90FY balance at the end the ball.

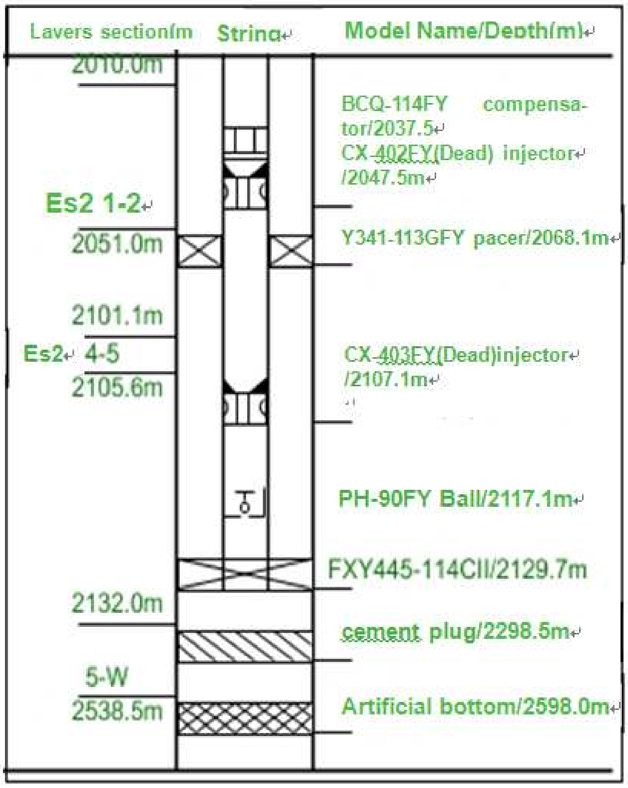


Figure 4. DXY17-41 wells column chart

On 7 March 2011, hoop, gamma, temperature, three-parameter test were taken on a section of the camp 17-41 wells. First, under normal circumstances water tests, 1890-2090 meters measuring well section; then shut parked Note 30 minutes for the second test, measurement, well section 1890-2090 meters. Test curve was completed, tools were clear, and test data was qualified. After replaying data, we use natural gamma curve to interpret the raw.

Table 2 DXY17-41 wells magnetic positioning data sheet

Instrument	Completed depth (m)	Opening test depth (m)	Shutting test depth (m)	Tool creep value (m)
Compensator		2035.5	2035.5	0
402 Water distributor	2047.5	2047.6	2047.6	0
Y341-113 Packer	2068.1	2067.5	2067.5	0
403 Water distributor	2107.1	2107.3	2107.1	0.2

Using the analysis software to calculate 33 dispensing wells string stress analysis, in which 11 wells packers are bad force situation. Analysis shows that this will affect the Packers analysis is valid. In addition, minutes layered string optimized design calculations were carried on for 22 injection wells, reducing the axial extent of the packer force.

Analysis of the results shows that: As with compensation, to offset the upper pipe string generated by a variety of stress, can effectively relieve packer force, so the force is less than the packer maximum static friction cones, not peristalsis occurs. The results coincide with the actual test results.

CONCLUSION

(1) Re-established a string of force model and temperature field model taking into account the different tools, such as anchoring impact tool length compensation tools ‘ effect to force the packers to make the results more realistic ;
(2) Supporting the anchor compensation measures will help to improve the force situation of packer in a variety of conditions, thereby extending the validity of the packer.
(3) Through the tubing string and packer stress analysis and calculation, stratified water column structure in order to optimize and ex-tend the life of the packer provides a theoretical basis.

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