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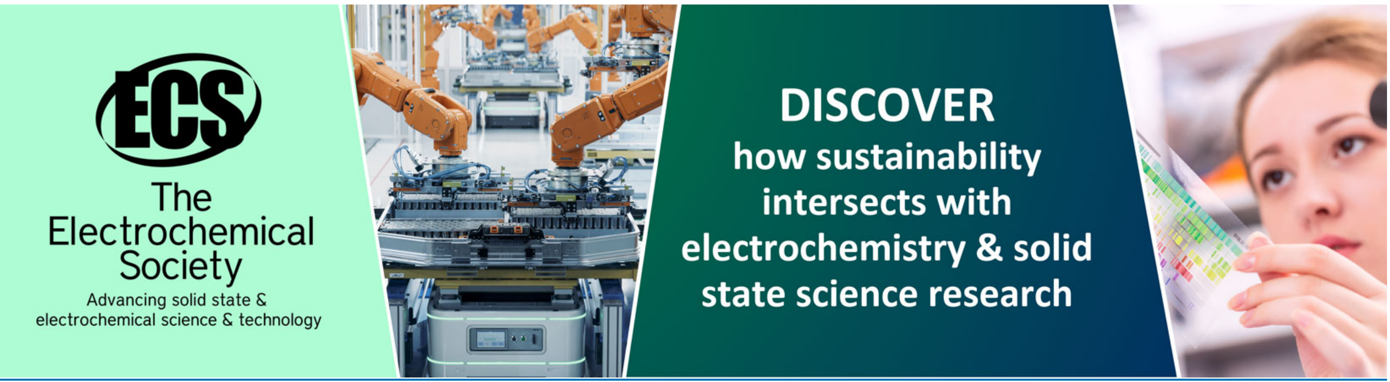

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Study on Flow Field Characteristics in Deflecting Section of Shale Gas Horizontal Well

Pei He [1, 2, *], Zhaohui Lu [1, 2, a], Ye Zhang [1, 2, b], Yi Zhang [1, 2, c] and Chun Meng[1, 2, d]

[1] National and Local Joint Engineering Research Center of Shale Gas Exploration and Development, Chongqing Institute of Geology and Mineral Resources, Chongqing 400042, China.
[2] Key Laboratory of Shale Gas Exploration, Ministry of Natural Resources, Chongqing Institute of Geology and Mineral Resources, Chongqing 400042, China.

*Corresponding author e-mail: hepei131180@163.com, [a]289707601@qq.com, [b]172526199@qq.com, [c]34682423@qq.com, [d]34682423@qq.com

Abstract. In order to study the characteristics of flow field at different deflecting sections of shale gas horizontal Wells, actual downhole string model is established to study the bottom-hole and annulus flow field characteristics by numerical simulation technology. The results show that the variation of deviation Angle has little influence on bottom hole and near bottom annulus flow field. When optimizing construction hydraulic parameters, the influence of the variation of inclined angle on bottom-hole flow field can be neglected. However, the distribution of annular velocity far away from the bottom hole is different, and the flow field characteristics of high inclined angle well are better than others, it is not easy to form cuttings bed during in construction. But more attention should be paid to problems of rock carrying in the low angle deflecting section of well. The research results can be used to guide the optimization of construction parameters and focus on the difficult problems in deflecting section of shale gas horizontal Wells.

Key words: Horizontal well, Flow field characteristics, Deflecting section, Cuttings.

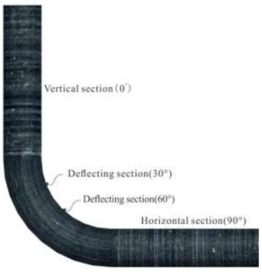
1. Introduction

As one of the most important well-types, horizontal well is widely used in shale gas development[1]. In the drilling process, cuttings tend to settle in deflecting and horizontal sections. It is a difficult problem to form cuttings bed. It can cause bottom-hole sticking, increase the torque of drilling tools and reduce the rate of mechanical drilling[2]. At present, a large number of scholars have solved these problems by optimizing drilling fluid properties, improving hydraulic parameters , configuring bottom-hole cuttings clearing tools and so on. Good results were obtained in the project. However, the above achievements are focused on horizontal sections of horizontal Wells, few researches have been conducted on drilling fluid flow rules in deflecting sections. In this paper, according to the 215.9mm wellbore trajectory characteristics of horizontal shale gas Wells, CFD technology is used to do numerical simulation research on the characteristics of wellbore bottom and annulus flow field in different deflecting sections, discuss and analyze the characteristics of flow field in the deflecting section of shale gas horizontal Wells.

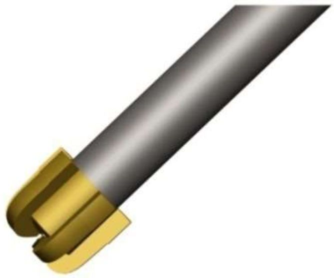
2. Computational model and boundary conditions

2.1. Computational model

The calculation model was built by Pro/E software based on the well trajectory and bottom hole string model (Fig 1). The size of borehole is Φ215.9 mm, the size of drill pipe size is Φ127 mm, the length of vertical section is 2500 m, the length of deflecting section is 800 m, the length of horizontal section is 1000 m in the well trajectory model. It contains PDC bit, Screw and LWD in bottom hole string model. The hydraulic structure of PDC bit has a great influence on the annular flow field, so the PDC bit structure model is further elaborated. The five blades are adopted(two main blades and three auxiliary blades), it is arranged in accordance with 0°, 70.4°, 146.9°, 217.9° and 285.2°[3]. There were two blade nozzles near two main blades (the diameter is 12.70mm, the nozzle inclination Angle is 15°), and three auxiliary blade nozzles (the diameter is 11.13mm, the nozzle inclination Angle is 25°) [4,5]. All nozzles are no nozzle holes.



(a) The well trajectory model



(b) The bottom hole string model

Figure 1. Numerical simulation physical model

2.2. Boundary conditions

(1) Assumptions. The fluid medium is oil-based drilling fluid. It is incompressible Newtonian fluid with solid liquid miscible phase. It ignores the phenomenon of heat transfer between fluids, the drill speed is 120r/min and the rotary speed is 40r/min.

(2) Initial condition. Working displacement is 45L/s. Turbulent kinetic energy k and turbulent dissipation rate ε can be denoted by[6,7]:

$$\varepsilon = \frac{\mu}{\rho}\overline{\left(\frac{\partial u_i}{\partial x_i}\right)} \tag{1}$$

$$\mu_t = \rho C_\mu \frac{k^2}{\varepsilon} \tag{2}$$

Where μ is the hydrodynamic viscosity, ρ the fluid density, u_i the velocity vector in the direction I, C_μ the empirical constant, 0.09 was selected in this study, μ_t the turbulent viscosity.

(3) Outlet condition. The wellhead is the outlet boundary, the exit pressure is 0, and the displacement is 45L/s.

(4) Wall boundary condition. Bottom hole, wall and bit wall were treated by wall function method. The fluid zone is configured for turbulence to develop fully. According to the standard two-equation model, the formula of wall face value and inner node value are adopted [8]:

$$u^+ = \frac{1}{\kappa}\ln\left(Ey^+\right) \tag{3}$$

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$$y^{+}=\frac{\Delta y_{p}\left(C_{p}^{0.5}k_{p}^{0.5}\right)}{\mu} \tag{4}$$

$$\tau_{w}=\rho C_{p}^{0.5}k_{p}^{0.5}u_{p}/u^{+} \tag{5}$$

Where κ is the Karman constant, It takes 0.4, E is 9.8, u_p the time average velocity of node p, k_p the turbulent kinetic energy of node P, Δy_p the distance from node p to wall, τ_w the shear wall, u^+ and y^+ are the dimensionless parameter.

3. Results

3.1. Characteristics of bottom-hole flow field

It shows the velocity distribution vector of bottom-hole flow field in different deflecting well sections in Figure 2. In the whole bottom-hole flow field, it is obvious that the fluid velocity ejected from PDC bit´s nozzles is the highest, which is the region that high speed and high energy fluid are concentrated, followed by the region where nozzles are directed at the bottom-hole. the velocity decreases sharply and the velocity distribution range is compressed sharply after the fluid enters the annulus. In addition, the turbulence in the down-hole flow field is obvious. Due to the uneven distribution of velocity and flow, a large number of vortexes appear in the bottom-hole. The overall characteristics of bottom-hole flow field do not change obviously with the variation of well inclination angle. Macroscopically, the distribution range of high - and low-velocity fluids is similar, and the velocity vectors between regions are complex and variable.

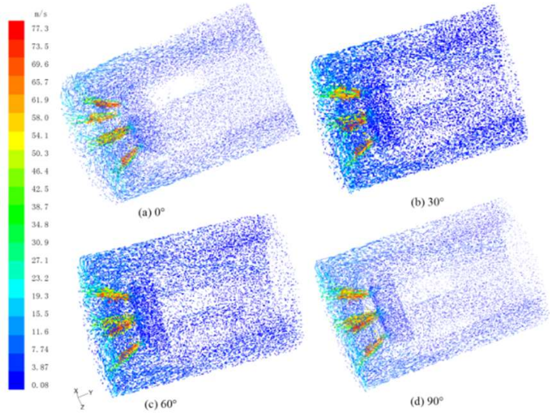
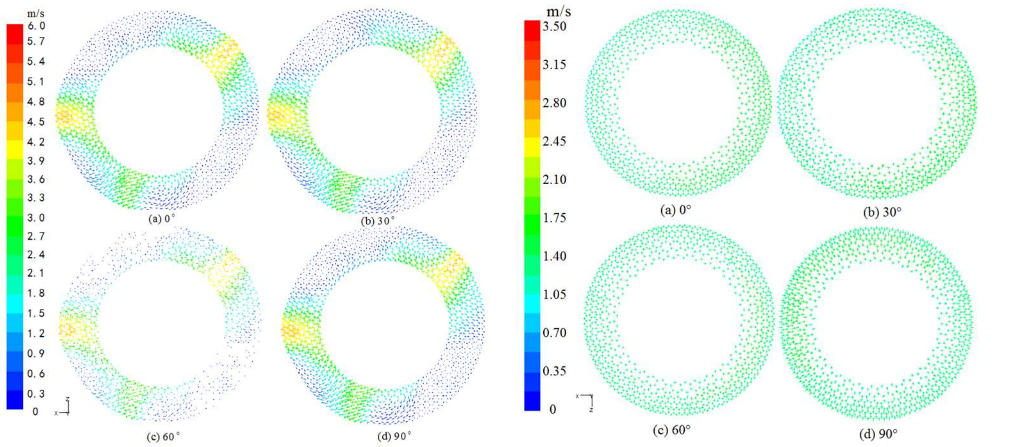


Figure 2. Velocity vector diagram of bottom-hole flow field in different deflecting sections

3.2. Characteristics of wellbore annular flow field

It shows the velocity distribution vector of the borehole annulus in different deflecting well sections in Figure 3. It can be seen that the annular fluid velocity decreases and the distribution range of velocity becomes more uniform with the distance increasing from the bottom-hole of well. Three high-speed regions are presented at 1 meter from the bottom-hole of well in Figure 3(a). These are mainly affected by the PDC bit placement of three peripheral nozzles. The three high-speed regions correspond to the three peripheral nozzles sprayed by the PDC bit. However, the variation of deflecting section has little effect on the velocity vector distribution of annular fluid. Annular fluid velocity distribution is uniform at 100 meters from the bottom-hole of well in Figure 3(b). The flow velocity in the central area of the annulus is larger than that in the area immediately adjacent to the drill pipe and wall. The variation of deflecting section has also no significant effect on the velocity vector distribution of annular fluid.



(a) Annulus from the bottom (1 m) (b) Annulus from the bottom (100 m)

Figure 3. Velocity vector diagram of wellbore annular in different deflecting sections

4. Discussion and Analysis

4.1. bottom-hole flow field

It is obviously that the maximum velocity and pressure decrease slightly with the increase of borehole angle in Figure 4. Although bottom-hole flow field are different in different deflecting sections, It has only a little changes. It can be ignored in engineering practice. Bottom-hole fluid is in a state of rapid and complex changes at the bottom-hole of well. Which are mainly influenced by Hydraulic construction parameters, PDC bit structure and downhole hydraulic tools, etc. Well skew is only a secondary influencing factor, which causes relatively small changes in the flow field at the bottom-hole of well. Therefore, when optimal bottom-hole hydraulic parameters of deflecting section of shale gas horizontal Wells are used to achieve optimal rock breaking, the influence of well inclination angle can be ignored. the execution can be carried out by referring to vertical Wells.

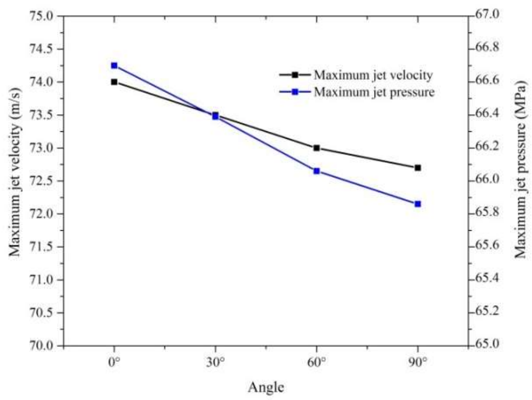
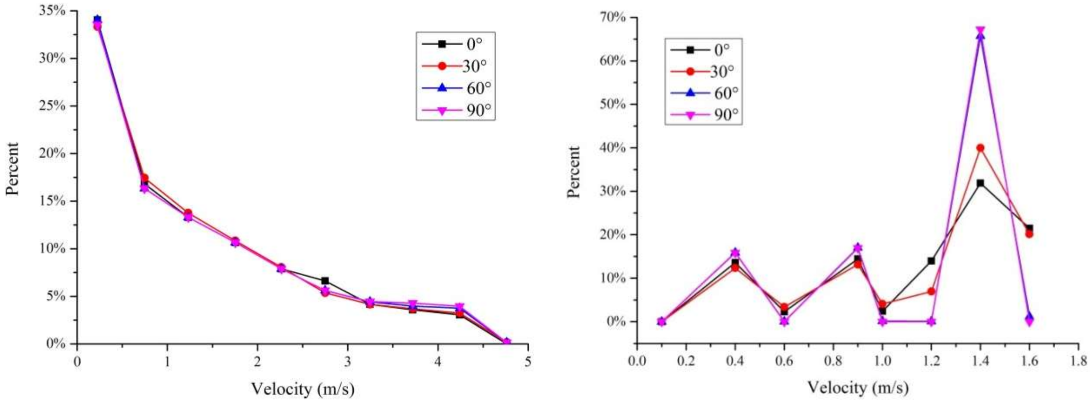


Figure 4. The maximum jet velocity and pressure of bottom-hole in different deflecting sections

4.2. Velocity distribution of borehole annular

It is found that the variation of the inclined angle in the deflecting section has little influence on fluid velocity distributions at 1 meter from the bottom-hole of well in Figure 5. The fluid velocity distribution accounted for less than 2% of the volatility in four different deflecting sections. Just like the flow field characteristics at the bottom-hole, it can be seen that the influence of the deflecting section change on the rock carrying capacity of the near-bit hole annulus can be ignored in engineering practice. The main factors are hydraulic construction parameters and PDC bit structure, etc. But the differences are large which is far away from the bottom of the well. With the increase of well deflecting, the distribution of annular fluid velocity varies greatly, especially the proportion range and equilibrium degree of high-speed fluid distribution vary greatly. The flow velocity is mainly concentrated in the range of 1.25-1.45m/s, accounting for 68% in the horizontal section or near the horizontal section. The distribution range of velocity increases, mainly from 1.15 to 1.65m/s in vertical or near-vertical section. It shows that the flow velocity in annular center is the largest, and the closer it is to wall or drill pipe, the smaller it is. The viscous effect of wellbore wall or drill pipe wall is obvious, which is not conducive to the rapid discharge of cuttings. However, it is less likely to form cuttings bed when drilling in deflecting section in engineering practice. When the annular flow field characteristics near the horizontal section are more conducive to rock carrying, easier to discharge cuttings stably, and the probability of cuttings sticking to wellbore wall and drill pipe is greatly reduced. If the engineering parameters and drilling fluid performance are stable, the cuttings bed should not be concerned during the construction of deflecting section drilling. Only pay special attention to the rock carrying problem during horizontal section drilling.



(a) Annulus from the bottom (1 m) (b) Annulus from the bottom (100 m)

Figure 5. Velocity ratio diagram of wellbore annular in different deflecting sections

5. Conclusion

This paper studies the characteristics of bottom-hole and annulus flow field to optimize carrying cuttings in the deflecting section of horizontal shale gas wells. The main conclusions are as follows:

(1) The variation of deflecting section has little effect on bottom-hole flow field. When optimizing hydraulic parameters, the influence of location change of deflecting section can be ignored.

(2)The cuttings carrying capacity of annular fluid near bottom-hole is mainly controlled by hydraulic parameters and PDC bit structure, etc. The influence of the deviation of the deflecting section can be ignored in engineering.

(3)The fluid flow field which is far away from the bottom-hole is greatly affected by the variation of deflecting section. It is necessary to pay attention to wellbore wall and drill pipe on cuttings viscosity effect in vertical section, but the influence is weaker in high-angle deflecting section.

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