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Numerical Simulation of Effect of Eccentricity on Annulus Pressure of Aerated Drilling

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Abstract
Aerated drilling can effectively solve the mud leakage, reservoir pollution and the critical question of the effect of productivity. It also can protect, find and correctly evaluate oil and gas resources. The technology of aerated drilling is applied to detailed exploration and step-out well of oil and gas field of low pressure, this technology has wide applications. Based on the previous researches, the effect of drill string under the condition of eccentricity on annulus pressure is considered in this paper. After in-depth investigations, annulus pressure of concentric and eccentric conditions are analyzed through the CFD numerical simulation, the distribution law of pressure of eccentric annulus along well depth is expounded. The following conclusions can be showed through the CFD numerical simulation: the annulus pressure of aerated drilling follows curve, the pressure decreases gradually from the bottom to wellhead. The pressure does not vary abruptly in the position of changing area of annulus cross-section, the reason is that the gravitational pressure drop plays the leading position in the annulus pressure drop. Liquid is incompressible fluid, although the gas volume is changed, the density of gas is small relative to the density of liquid, so the density of drilling fluid changes little in the variable cross-section. Under the same conditions, the flow pressure drop of eccentric annulus is less than concentric annulus.

Key words: Aerated drilling; Concentric annulus; Eccentric annulus; Annulus pressure; CFD numerical simulation

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INTRODUCTION
Aerated drilling has proved to be effective and economical in underbalanced operations and is gaining wider applications in many areas. The fluid of aerated drilling has low density and high blocking ability. It can effectively reduce leaking of fluid into formation in low-pressure wells and protect the oil formation[1-6]. This way of technique can improve drilling efficiency, reduce drilling cost and have a great potentiality to the petroleum recovery efficiency.

In 1995, Wang et al.[7] of Norway National Research Institute established more perfect dynamic theory model of underbalanced drilling in underbalanced drilling field at present in the world.

In 1996, assuming multiphase fluid can be seen as homogeneous mixture of three-phase of gas, liquid and solid, Guo et al established the calculation model for predicting the most optimal air injection rate and cuttings transport capacity[8].

In 1998, Zhou Kaiji established steady state model of multiphase flow of underbalanced drilling through calculating continuity equation of gas, liquid phase, momentum equation and energy equation[9].

In 2000, according to the mass conservation equation and the drift flow equation of gas phase and solid phase, Sharma et al. assumed that drilling fluid in drill pipe and annulus is in the condition of homogeneous flow and established heterogeneous steady flow model of two-phase flow in wellbore[10].

In summary, most of researches are based on pipe flow or concentric annulus flow, only a few researches considered the effect of the eccentric drill pipe on annulus pressure. In this paper, annulus pressure of concentric and eccentric conditions are analyzed through the CFD numerical simulation, the distribution law of pressure of eccentric annulus is expounded.

1. ANNULUS CYLINDER GEOMETRY MODEL

The annulus cylinder geometry model of vertical wells is shown in Figure 1. The well length is 1 m, the radius of outer tube is 0.1 m, the radius of inner tube is 0.06 m.

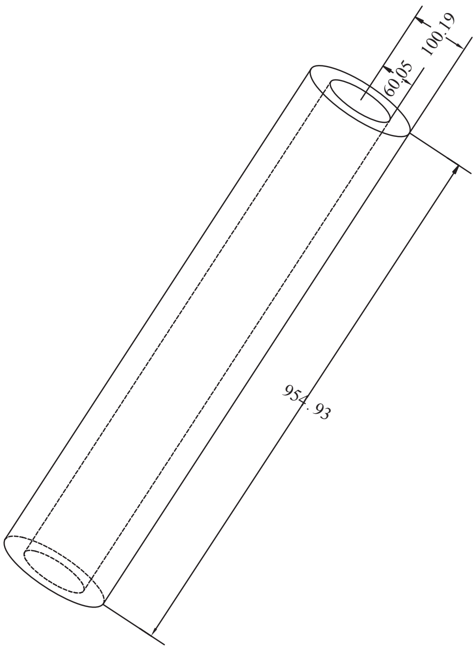

Figure 1
Annulus Cylinder Geometry Model

2. MODELING AND GRID PARTITIONING

The wellbore model of concentricity and eccentricity is established with Gambit 2.3.16. Taking the concentric wellbore, we introduce the process of model establishment and grid partitioning.

First of all, the column model is drawn according to the geometric size of annulus column.

The line of the direction of Z axis is divided 200 segments, all the arcs of the round surface of annulus column is divided 40 segments. As shown in Figure 3, separately meshing of line, face and volume, the grid of annulus column is acquired.

Figure 2
Annulus Column

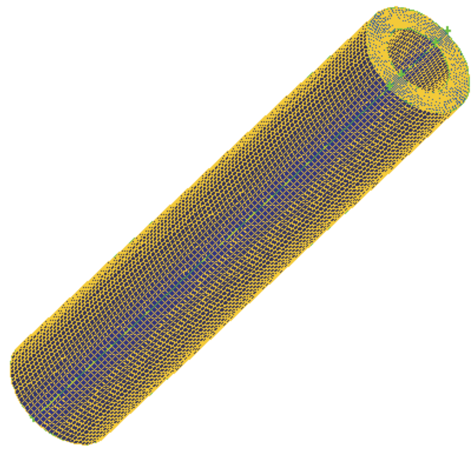

Figure 3
Grid Partitioning of Annulus Column

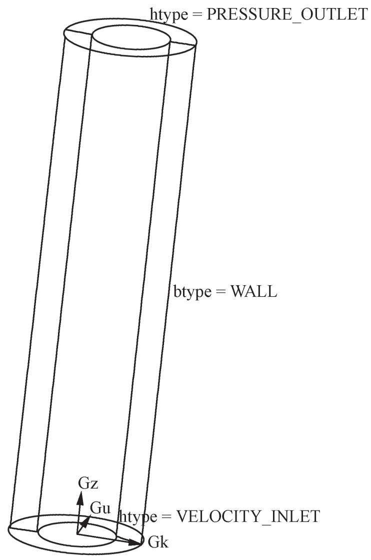

Figure 4
Defining Column Boundary Type

According to the requirements of simulation, the boundary type of annulus column is defined. We define that the torus of XOY plane is "velocity inlet" and the torus of $Z = 1$ plane is "outlet pressure". The Figure 4 is shown.

3. SOFTWARE SETUP

Some basic settings of software, using the simulation of this paper, are listed in Table 1.

Table1
The Basic of Software

Setting categories	Setup instructions
Multiphase flow model	VOF Model
Computational Grid	hexahedron
Per unit length of model	m
Inlet velocity of mixed-phase	To be set according to calculation needs
Outlet pressure of mixed-phase	To be set according to calculation needs
Volume fraction of liquid phase	To be set according to calculation needs
Viscosity model	k-epsilon (2 eqn)
First phase materials	Air
Section phase materials	Water
Relaxation factor	To be set according to calculation needs
Time step	0.001-0.0025
Iterations	1,000-3,000

4. THE SIMULATION RESULTS AND ANALYSIS

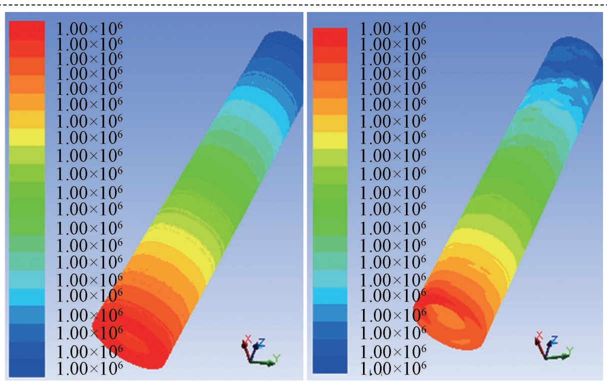

Figure 5
Pressure Distribution of Annulus Cylinder of Concentric Annulus and Eccentric Annulus

As shown in Figures 5 and 6, the two-phase fluid of gas-liquid flows upward along Z axial, the annulus pressure varies from large to small. When the same "outlet pressure" is set, the annulus pressure of lower part of concentric cylinder is slightly greater than the annulus pressure of lower part of eccentric cylinder.

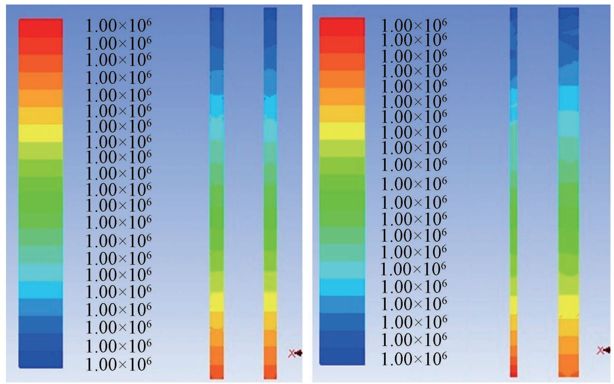

Figure 6
Pressure Distribution of Longitudinal Section of Concentric Annulus and Eccentric Annulus

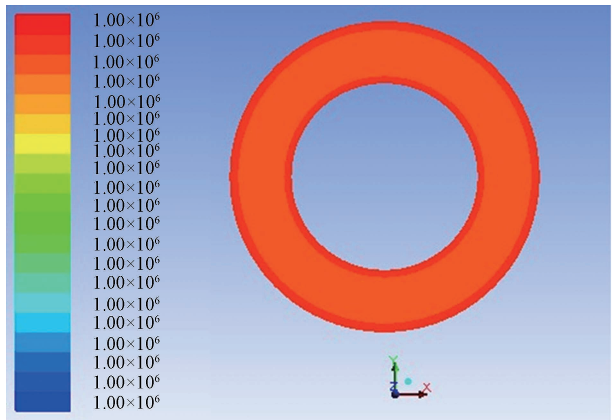

Figure 7
Pressure Distribution of Inlet Cross-Section of Concentric Annulus Cylinder

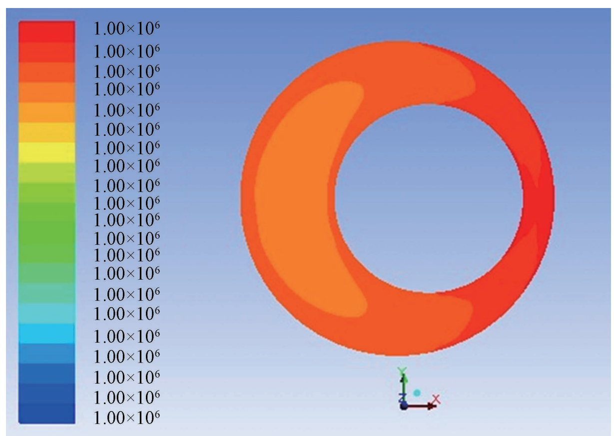

Figure 8
Pressure Distribution of Inlet Cross-Section of Eccentric Annulus Cylinder

As shown in Figures 7 and 8, the cross-section pressure of concentric annulus is symmetrical about the X axis and Y axis, the pressure at the middle of annulus is lower. The cross-section pressure of eccentric annulus is symmetrical about the X axis, the annulus pressure of narrow gap is higher than the annulus pressure of wide gap.

CONCLUSION

The annulus pressure distribution of aerated drilling follows curve, the pressure decreases gradually from the bottom to the wellhead, the pressure does not vary abruptly in the position of changing area of annulus cross-section, the reason is that the gravitational pressure drop plays the leading position in the annulus pressure drop. Liquid is incompressible fluid, although the gas volume is changed, the density of gas is small relative to the density of liquid. So the gas-liquid density changes little in the variable cross-section. Under the same conditions, the flow pressure drop of eccentric annulus is less than concentric annulus.

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