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Simulation Based on CFD of Drilling Fluid Screening Process

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Abstract: ***Screening process through the establishment of a mathematical model to calculate the amount of processing shaker is difficult, complex process, low accuracy. In this paper, based on the CFD simulation of the drilling shaker screening process which realized the drilling fluid flow through sieve and the free surface of liquid flow visualization simulation. The screen mesh and mud cake with a series of porous media simulation, the dynamic meshing technique was adopted to achieve the the vibrating screen's movement of drilling fluid on the surface of the screen. Analysis of multiple parameters (such as screen mesh, vibration frequency) on the influence of drilling fluid flows through screen. Research results show that the proposed method of CFD to calculate the rate of the drilling shaker is feasible. Have a important reference value to solve the problem of capacity calculation .***

Keywords: Vibration Screening; Handling Capacity; Drilling Fluid; CFD

1. Introduction

Shale shaker screening process is a complex and dynamic process. The flow of drilling fluid includes a flow through the screen surface and screen flow. Its entire flow process will be affected by the vibration frequency, amplitude, sieve mesh, and many other factors which is transient and flow pattern will change due to the parameter changing. Vibrating screen on the solid control system plays a key role quite, and the screen surface drilling fluid free surface flow is very important to improve the vibrating screen various aspects performance.

Wei-bing zhu [1-2] established a pure movement on the surface of the drilling fluid along the vibrating sieve and continuous flow equation which is based on basic principle of hydrodynamics, and adopting the principle of all can respectively, average method and finite difference method to the equation but did not consider solid relative drilling fluid through the influence of the screen .Jun-feng zhan [3]by using of solid-liquid two-phase flow theory establish a drilling fluid shale shaker screening model, and the factors affecting the screening efficiency and capacity are analyzed, but there is no drilling fluid capacity calculation method of the vibrating screen is established. Vidya Raja [4-5]who proposed a continuous model of vibrating screen such as floods the mud as the mud cake filtration model, established the control equation of mud cake and the capacity of drilling fluid calculation method, and through the field experiment. Zong-ming wang [6] using PHOENICS software established drilling fluid through sieve calculation model, and simulate the fluid dynamic pressure drop coefficients through screen, but not considering the influence of solid phase and complete model of liquid interaction effects.

The all above study unable to clearly describe the free liquid surface transient changes which is difficult to meet the needs of engineering practice. This article adopts the universal method of computational fluid mechanics, disposing the screen and mud cake on the surface of screen as the porous media model for the tandem [7-8].Dynamic grid technique are adopted to simulate the vibration movement of the vibrating screen to analysis the parameters of screen mesh and vibration frequency effect on the rate of vibrating screen. The drilling shaker capacity calculation method which established in this paper, overcomes previous study that need special calculating program, shortcomings and make assumptions on dynamic free surface. The screening process visualization was realized.

2. Establishment of Screening Simulation Model

This study that based on the CFD fluid simulation principle established the model of vibrating screen (see figure 1) simulation. Drilling flowed from the flow inlet, and flowed through the buffer stage go into mud cake and the surface of the screen. When drilling fluid gradually flowed through the mud cake and screen surface they exported from through sieve out. Free outlet is used for air exchange which mainly have the effect of equilibrium pressure.

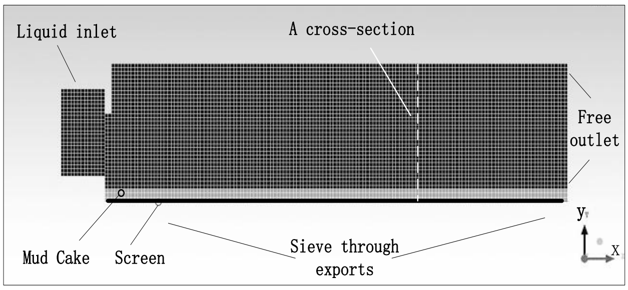


Figure 1: Vibrating screen model

2.1 Calculation Model

The laws of fluid motion is based on the conservation of mass, the conservation of momentum and the conservation of energy. In this paper, it isn't considering heat transfer problem, so don't discuss the conservation of energy.

Considering the real environment (air exist in the real environment), choose to simulate the multiphase flow in the CFD software which choose the RNG $k-\varepsilon$ turbulent model in the case of VOF model as multiphase flow [9].

According to the working condition of drilling fluid shale shaker, we define phase and air drilling liquid in the simulation respectively .The parameters of the air phase is the atmospheric pressure parameters. Set the drilling liquid according to the actual situation of drilling fluid density value is 1, 180 kg/m3, viscosity of 0.05 $\text{Pa}\cdot\text{s}$ [10].

Screen mesh is defined as 2 mm thick porous medium. Build a layer thickness of 10 mm lower resistance coefficient of porous medium as the mud cake model on the screen. Due to the porous medium model and the mud cake on the form and principle is very close, so the mud cake layer above the screen mesh set as different resistance parameters of porous media [4].As shown in figure 2.

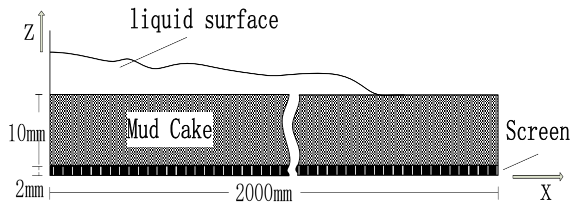


Figure 2: Screen mesh with mud cake structure

2.1.1 Mesh Porous Medium Resistance Coefficient of the Model

Inertial resistance coefficient, viscosity resistance coefficient, fluid direction vector and porosity are the physical parameters of porous plate. Screen can be viewed as the pore evenly arranged porous plate, so the momentum equation in porous media due to the penetration of viscous drag coefficient can be ignored. We just consider its inertia resistance coefficient going through the screen mesh.

In the simulation of porous plate, porous medium equation for [11] :

$$\nabla p = -\sum_{j=1}^{3} C_{2ij}\left(\frac{1}{2}\rho v_j |v|\right) \qquad (i = x, y, z) \qquad (1)$$

Or pressure drop in three coordinate directions:

$$\Delta p_i = -\sum_{j=1}^{3} C_{2ij}\Delta n_i\left(\frac{1}{2}\rho v_j |v|\right) \qquad (i = x, y, z) \qquad (2)$$

Type: ∇p said gradient; Δp is pressure drop; C_{2ij} is inertial resistance coefficient matrix in C2 items; Δn_i is the thicpressurekness of the porous medium in three directions; ρ is fluid density.

Van Winkle et al. [12] deduce the formula about the turbulent flow experiment of through porous plate:

$$m = CA_f\sqrt{(2\rho\Delta p)/(1-A_f/A_p)^2} \qquad (3)$$

Among them: m is through the total capacity of the perforated plate; A_f is the area of the all holes on perforated plate; A_p is the area of the porous plate; C is the coefficient which time change with Reynolds number and D/t (the ratio of hole diameter and thickness) .When $D/t >$ 1.6, and the Reynolds number of Re> 4, 000, C approximation is equal to 0.98. And $\dot{m} = \rho v A_p$, On both ends of the formula (3) after the square divided by the thickness of the screen:

$$\frac{\Delta p_z}{\Delta n_z} = \left(\frac{1}{2}\rho v^2\right)\frac{1}{C_2}\frac{(A_p/A_f)^2 - 1}{t} \qquad (4)$$

V is observation speed in the formula. Define i = z, compared with the formula (3) can getinertial resistance coefficient along the direction perpendicular to the surface:

$$C_2 = \frac{1}{C^2}\frac{(A_p/A_f)^2 - 1}{t} \qquad (5)$$

Different sieve mesh number corresponding to the porosity and drag coefficient are shown in table 1.

Table 1: Different screen mesh corresponding to the porosity and the drag coefficient

Screen mesh	40	80	120	160
Screen mesh diameter/mm	0.50	0.22	0.15	0.11
Porosity score	0.56	0.51	0.50	0.49
z direction of the inertial resistance coefficient C2 /m^{-1}	1 519	1 974	2 028	2 196

By setting the porous medium resistance and porosity in x and z direction is to realize simulation of mesh and mud cake. This paper defines the z direction as the first direction (vertical)and x direction as the second direction (horizontal).The flow of fluid go through the screen mesh just along the direction of the mesh (z direction), So when the direction of resistance load , the horizontal resistance coefficient is bigger than 2 ~ 3 orders of magnitude along the direction of the mesh , to ensure that the fluid inside the screen does not flow. In this example the z direction of the horizontal resistance coefficient of x is 1, 000 times.

2.1.2The resistance coefficient of porous media model for mud cake

When drilling fluid flowed through the mud cake model we set its resistance coefficient in two directions are the same due to considering the actual mud cake is similar to the packed bed structure[4].The drag coefficient calculation method use semi-empirical formula to determine:

$$C_2 = \frac{3.5(1-\varepsilon)}{D_p\varepsilon^3}, \qquad (6)$$

$$\frac{1}{\alpha} = \frac{150(1-\varepsilon)}{\varepsilon^3 D_P^2} 。 \quad (7)$$

In above equations, C_2 is inertial resistance coefficient, and $\frac{1}{\alpha}$ is viscous resistance coefficient. D_p is the average particle size, and ε is pore fraction.

Assuming uniform particle flat on the screen, because the particle diameter is slightly bigger than the screen hole size, particles on the sieve surface projection area fraction of the entire screen is close to the screen porosity [13], mud cake layer porosity fraction can be approximately regarded as $\varepsilon_{mudcake} \approx (1-\varepsilon_{Screen})$.

Computes the mud cake of viscous resistance and inertial resistance coefficient is shown in table 2.

Table 2: The mud cake layer resistance coefficient of porous media

Screen mesh	40	80	120	160
Average particle diameter/mm	0.60	0.32	0.25	0.21
Porosity fraction	0.44	0.49	0.50	0.51
Coefficient of inertia $/C_2 \cdot m^{-1}$	3.83×10^4	4.74×10^4	5.6×10^4	6.15×10^4
Viscous drag coefficient$/m^{-2}$	2.73×10^5	6.34×10^5	9.6×10^6	1.25×10^7

2.2 The boundary conditions

The boundary conditions are mathematical and physical condition variable in the calculation of the flow field boundary should be met. After determining the boundary and initial conditions, the solution flow field only exists, and is the only solution.

Entrance set as flow entrance conditions. Drilling fluid is divided into screen extension direction of export (exposure) and export through the screen mesh which is on the screen, and we select the pressure conditions for export.

Dynamic grid model can be used to simulate the flow field due to the motion of the boundary shape change over time. Drilling fluid shale shaker screen mesh which points in the process of simulation is a typical dynamic grid. Initial definition of the dynamic grid should be given before the calculation, and the boundary deformation process can be used to define the boundary function.

According to the vibration movement of the vibrating screen, dynamic meshing boundary function of screen mesh can be defined as:

$$Vx = A\cdot\omega\cdot\cos(\omega\cdot t + a) \quad , \quad (8)$$

$$Vz = A\cdot\omega\cdot\cos(\omega\cdot t + a) \quad 。 \quad (9)$$

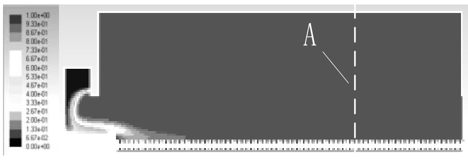
At work for mud cake and sieve movement, the simulation without relative displacement method is used to simplify the complex model.

3. The Results of Simulation and Analysis

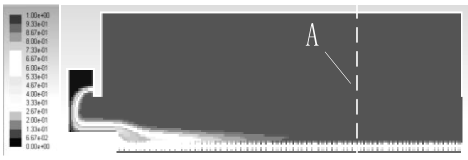
3.1 Drilling Fluid Flow along the Screen Surface Analysis

To analyze 80 mesh, drilling fluid to 59L/s from the entrance into the screen surface until in the sieve surface liquid phase termination position is basically stable. The flow of drilling fluid with T at different time is shown in figure 3. It can be seen that the drilling fluid from the entrance through the buffer table with the screen, full screen penetrating from exposure to 1/3.

（a）T=0.6 s



（b）T=0.9 s



（c）T=1.5 s

（d）T=2.4 s

Figure 3: Drilling fluid changes on the surface of screen

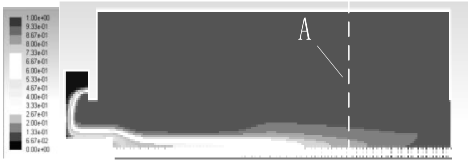
3.2 The number of screen mesh on the impact of the flow through the screen

Respectively take sieve mesh number 40, 80, 120, 160, when the screen liquid position basically stable, liquid clouds on the surface of the screen as shown in figure 4.

(a) 40Mesh

(b) 80Mesh

(c) 120Mesh



(d) 160Mesh

In section A (x=1400mm) by the monitoring traffic, and then calculate the average of fluid. The results are shown in table 3.

Table 3: Different screen corresponding parameter table

Screen mesh	40	80	120	160
A cross section flow/kg·s^{-1}	0.713	2.287	3.482	4.972

It can be seen that drilling fluid free surface extended gradually due to the increase of number of screen mesh, and the sieve coverage is more and more big.

3.3 Influence of vibration frequency to flow through sieve

Based on the 80 mesh sieve, different frequency correspond to A cross section of flow monitoring data are shown in table 4.

Table 4: The simulation results of different frequency

frequency/Hz	10	20	30	40	60
A cross section flow/（kg·s^{-1}）	4.310 3	4.159 0	4.082 3	3.549 1	2.740 8

It can be seen from table 4 that with the vibration frequency strengthen, A cross section of flow to reduce gradually, and the boundary position of the sieve through move forward with increased frequency of vibrating screen through sieve ability enhancement.

3.4 Verification Experiment

It can be seen from the figure 3, after the drilling fluid from the inlet flow into the shaker flow conditions gradually stabilized.

Take 80-mesh sieve through simulation results of flow with the same parameters measured through the shale shaker screen flow for comparison. Experimental measurements of the flow through the sieve weight is measured by reading the experimental vibration sieve container beneath the drilling fluid.

Flow through sieve measured value and simulated values were 51.83 L / s and 56.71 L / s, the error of 8.6%; Found analog values A section was 2.04 L / s and 2.28 L / s, the error value of 10.5% .

The result of simulation is slightly larger than the experimental values, and error mainly from the following two factors:

1) Due to Drilling Splash and adhesion, the actual quality of the measurement is not conserved, so the actual flow through the sieve slightly less than the analog value.
2) Due to the presence of particles in real drilling mud unconventional individual screen sizes larger area causing blockage, so the actual measured flow through smaller screen.

4. Conclusion

Use drag coefficient which is much Larger than the transverse direction of the flow through the sieve drag coefficient of porous media model to simulate drilling shaker screen, and the use the dynamic mesh to achieve the effect of vibratory motion shaker screen surface of drilling fluid; the sieve surface on the basis of cuttings cake model considerations, with the lateral drag coefficient and flow in the same direction through the sieve drag coefficient of porous media model to simulate the cake; cake porous medium model and mesh porous medium model system consisting of a series of simulation constitutes a vibrating screen screening model. The results show that the simulation model established in this paper can simulate the process of screening the drilling fluid in the shaker.

The simulation process can monitor the form of free surface and the screen surface drilling fluid flowing through the screen which can easily be found in the drilling fluid flowing through the sieve and the law of the screen surface, the more quickly calculation processing shaker the amount of on-site help guide the drilling process.

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