Numerical Simulation Based on High Pressure Jet Mud Impact Technology

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Abstract: Since crude oil is composed of colloidal solution, solid hydrocarbon, asphaltene, and fine sediment dispersal, the problem of sludge deposition will occur after the long-term operation of the underground crude oil storage. The high shear rate produced by the jet has a suction effect on the sludge. Based on the advantages of groundwater sealing reservoirs, this study uses CFD software to study the jet flow of underground crude oil reservoirs, and analyzes the effects of the flow on the sludge and the changes of the flow with time. The research shows that the jet stream has impact and entrainment in the convection field, and the jet at a certain speed can make the flow field circulate as a whole, and dissolve the sludge at the bottom of the reservoir. The energy of submerged jet decays rapidly in the process of advance.

1. Introduction

At present, China has become a developing oil consumer, but China has a relatively poor country with oil and gas resources. With the rapid development of the economy and the rapid increase in energy demand and consumption, the establishment of the necessary petroleum strategic reserves plays an important role in ensuring the sustainable development of the national economy and responding to emergencies. Because the underground water seal storage has the advantages of less land occupation, less investment, less loss, less pollution, low operating cost, high safety performance, fast loading and unloading, etc. This oil storage method has been adopted by more and more countries[1]. The research and construction of underground caverns in China started relatively late. At present, only a few small underground water seal caverns have been built, and the scale and design reserves are small, which is far from meeting the needs of national petroleum strategic reserves. It is imperative that large underground water sealed caverns store oil and store gas. Crude oil is a mixture of various low molecular hydrocarbons, heavy organic paraffin, asphaltenes and colloids. When the crude oil is in a static storage state, the condensable material in the crude oil carries sediment and settles under the action of gravity. Solid sludge deposits. The long-term accumulation of sludge not only affects the storage space, but also causes the oil quality to be uneven, which seriously affects the economic benefits of the storage tank. This phenomenon is more prominent with the increase in tank capacity [2-3].

The jet-type can cleaning technology is the most commonly used one in the domestic tank cleaning technology. After the high-pressure jet is pressurized by the pressurizing device, the medium is sprayed onto the surface of the deposit under a certain pressure and flow rate, and is generated by the jet. The high-speed shear rate, as well as a large number of vortex impacts, sucks the sludge, causing the bottom of the tank to gradually break from the state of the entire knot, and then dissolves to restore the standard quality of crude oil[4]. During the cleaning process, the speed of the jet directly affects the impact of the impact. In this paper, the jet agitation technology is applied to the dredging work of underground storage. The pre-processing software Gambit is used to model and draw the grid, and the calculation software FLUENT is imported to calculate the flow field in the reservoir during the simulation of the jet flow. The design of the cavern jet mixing system provides a reference.

2. Introduction of simulation method

The calculation is carried out using FLUENT16.0 software. It is assumed that the fluid is a continuous and incompressible Newtonian fluid. The flow in the cavern is isotropic turbulence. The turbulent basin is calculated by the standard k-ε two-equation model. The multiphase flow is calculated by the Eulerian model. The simulation solves the equation, the discrete model uses the finite volume method, the flow phase adopts the differential correction of the delay correction, and the diffusion phase adopts the first-order upwind difference format. The pressure relaxation factor is set to 0.3, the momentum is 0.7, and the kinetic energy is 0.8, the dissipation rate is 0.5. Pressure and velocity coupling is solved by SIMPLE pressure correction method. Momentum, kinetic energy and dissipation rate are used in second [5-6].

3. Numerical simulation

3.1. Geometric Model and Meshing

Taking a 20m×30m×500m volume as a 3×10^5 m^3 groundwater sealing cavern as an example to simulate the jet impact process, the result of the jet system and pipeline attachments is complicated, which leads to the complexity of the grid and affects the calculation results. The internal structure of the jet system. It has little effect on the simulation of the jet flow field, simplifying the structure of the nozzle and the jet system to meet the speed export requirements.

3.2. Boundary conditions and physical parameters

General setting selects the influence of transient flow and gravity in the Y-axis direction. The nozzle inlet boundary condition of the calculation model is set to the velocity inlet boundary condition, the nozzle exit boundary condition is set to the interior boundary type, and the nozzle boundary condition is the default non-slip boundary. The same kind of oil jet impact is adopted, and the physical properties of the jet fluid are as follows. The following table 1:

Table 1. Fluid properties of jet fluid

Crude oil density Kg/m^3	Crud oil viscosity Kg/(m.s)	Sludge density Kg/m^3	Sludge viscosity Kg/(m.s)	Jet fluid density Kg/m^3	Jet fluid viscosity Kg/(m.s)
800	0.02	929	0.08	800	0.02

3.3. Initial state setting

In the initial state, the two components are assumed to fill the entire underground reservoir in a layered form, and under gravity, the first phase of the highest density sludge is located at the bottom of the underground reservoir, and the upper part of the sludge is filled to the top of the reservoir. The main item is sludge and crude oil is the second item. Figure 1 shows the initial stratification distribution of each phase.

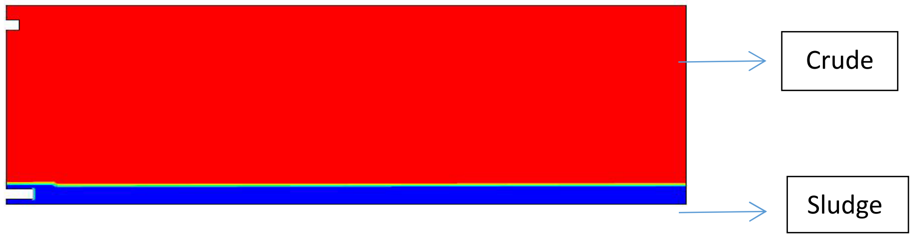

Figure 1. Two initial distributions of the model on the Y=0 plane

4. Comparative analysis of simulation results

According to the actual working conditions of the onshore storage tank clearing tank, the impact of the different thickness of the groundwater sealed cavern is numerically simulated, keeping the incident velocity of the nozzle 20m/s, the thickness of the sludge being 1m, and analyzing the jet stream to the sludge. The law of impact changes with time.

4.1. Speed cloud and speed vector

When the jet stream enters the static reservoir, there is a section of unequal velocity between the jet and the stationary fluid. The section is disturbed, and the surrounding fluid and sludge enter the jet, causing the stationary flow field to be disturbed. The jet emerges in the horizontal direction and moves along the bottom of the reservoir. It has different degrees of disturbance to the fluid in the horizontal and vertical directions. The horizontal jet has an impact on the sludge. Particles in the horizontal and vertical directions are constrained by the reservoir wall and the top of the library, forming a loop inside the reservoir.

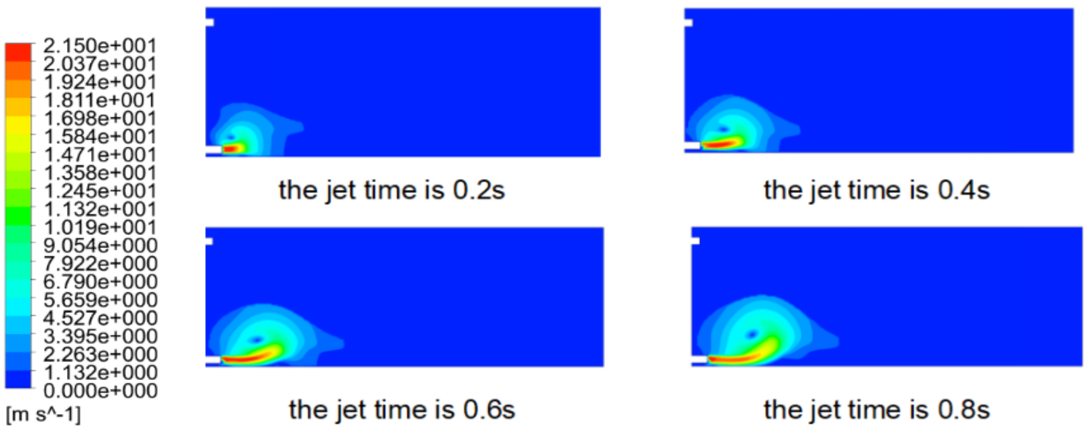

Fig 2. Velocity cloud map in the flow field at different times when the sludge thickness is 1 m

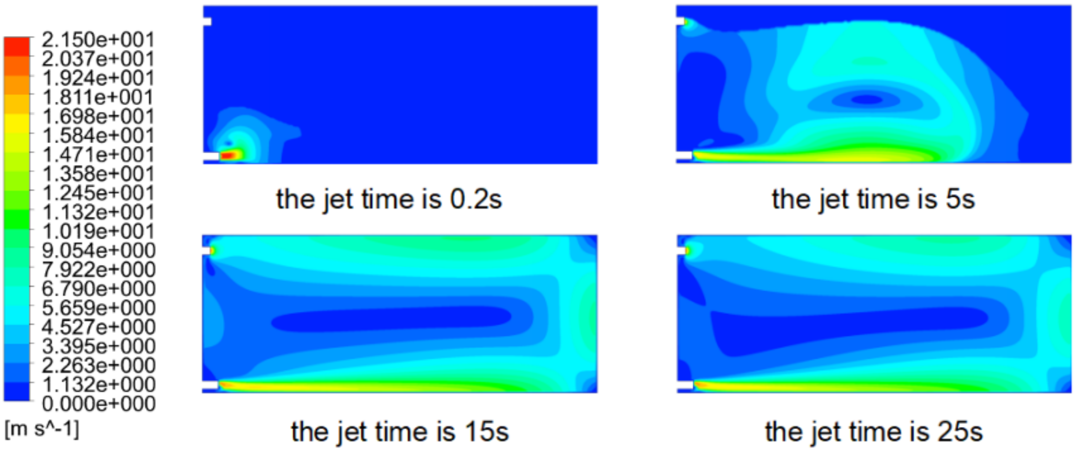

Fig 3. Velocity cloud map in the flow field at different times when the sludge thickness is 1 m

The incident velocity of the nozzle is kept at 20 m/s and the thickness of the sludge is unchanged at 1 m. It is found that the flow field of the reservoir has no significant change when the jet duration is 0.2s. When the jet duration is 5s, the bottom of the reservoir, the sludge and the upper crude oil form a small-scale cycle; as the jet time increases, the perturbation range of the jet stream to the sludge gradually becomes larger, and the overall circulation of the internal flow field of the reservoir is formed. When the jet duration is 15s and 25s, the velocity map of the flow field does not change significantly. Therefore, as the jet duration increases, the energy attenuation of the stream in the flow field is intensified, and the impact range of the flow field is gradually reduced.

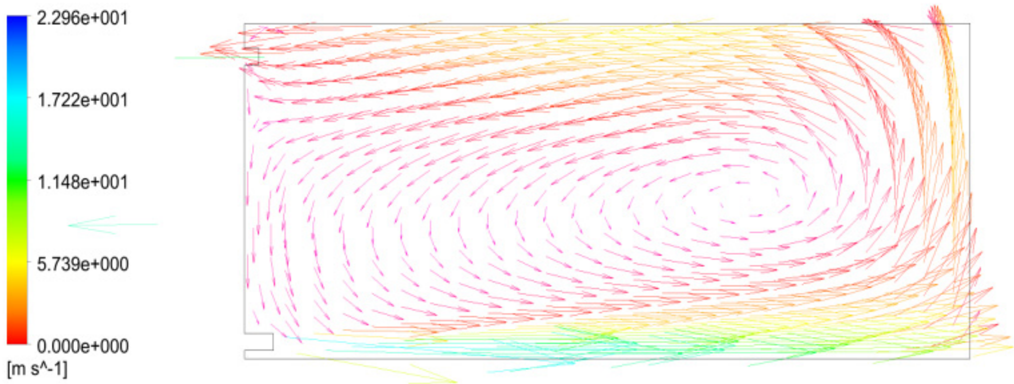

Fig 4. Flow field internal speed vector

The velocity vector diagram can more intuitively reflect the disturbance of the jet stream to the internal flow field of the reservoir. Near the jet outlet, the flow velocity is the largest. As the jet time increases, the energy of the stream gradually decreases and the flow rate decreases accordingly. The internal flow field is gradually changed from a local small cycle to an overall cycle.

4.2. Flow rate change

More intuitive analysis of the effect of jet stream on the impact of sludge, three coordinate, points are selected in the flow field, and according to the data corresponding to the coordinate points of Table 2, the velocity trend of the sludge at the bottom of the reservoir with the jet stream is plotted.

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Table 2. parameter coordinate points

point	Point1	Point2	Point3
coordinate	（2.5,0.75）	（10，0.75）	（18,0.75）

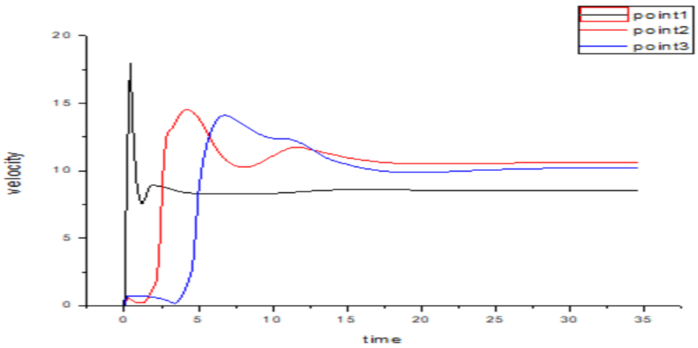

Fig 5. sludge speed change curve

According to the coordinate points of Table 3 and the curve trend of Fig 5, it can be found that when the outlet velocity of the nozzle jet is 20 m/s, the overall trend of the sludge velocity at time 1, point 2, and point 3 changes with time, and the flow rate first increases with time. Increase, after increasing to a certain peak, gradually decrease to a certain value and tend to be gentle. The velocity of the sludge at point 1 increases rapidly to the peak with the jet stream, and then the energy of the stream inside the flow field is attenuated. The sludge speed at this point also drops to a certain value. After falling to the lowest point, the speed remains basically the same. Point 2 is far from the jet outlet. The sludge at this point is just beginning to be fluctuated by the flow field, and the speed fluctuates slowly. When the jet stream hits the point, the speed rapidly increases to the peak value, and then the attenuation value is a certain value; When the jet outlet is far away, as the loss of the stream energy increases, the entrainment and impact force of the sludge is correspondingly reduced, so the peak velocity of the point is correspondingly low. Since the jet stream enters the stationary flow field, the energy loss of the impact sludge is more, so the sludge flow rate at point 1 is attenuated more.

5. In conclusion

Combined with the actual operating conditions of the underground crude oil storage, the Gambit model was used to simulate the high-pressure jet impact technology using FLUENT software, get the speed change of the internal flow field in the reservoir. The velocity cloud map is analyzed to obtain the impact disturbance of the flow on the sludge and flow field. The jet velocity of 20 m/s has a strong crushing and dispersing ability, and the internal disturbance of the flow field is good. After a certain time, the whole flow is formed inside the flow field; the jet stream spreads to the surrounding during the forward process, and the energy loss is large. This results in a decay along the axial velocity, which remains essentially constant after decaying to a certain value.

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