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# Research on Sealing Technology of Waste Well Cement Slurry

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## Abstract
With oilfield development, a large number of injection-production old wells due to mining for a long time have entered into the phase of scrap and have a bad effect on the oil field development and production, how to seal the abandoned well, which is not affected by other production well, we need to focus on. In this paper, by means of numerical simulation, the variation law of the mud diffusion distance in different construction conditions is simulated, and the corresponding cement slurry sealing parameters are selected to improve the sealing effect of the abandoned well.

**Key words:** Cement slurry sealing; Rheological property; Diffusion velocity; Sealing radius

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## INTRODUCTION

In the process of development and production of oil fields in our country, the development of a large number of abandoned wells becomes a burden to the development of oil fields, which seriously restricts the development of oil field[1-2].

For the abandoned well, the oil field is generally used to seal the cement grouting. Cement grouting is a theory of fluid mechanics and solid mechanics, which describes the flow law of the characteristics of the formation of the injection pressure injection flow, cement slurry diffusion radius and other parameters. Cement slurry is often in a variety of forms, and these forms of movement are transformed or coexist with the change of the formation, the nature of the slurry and the pressure[3]. Although the cement slurry is very complicated in the form of the formation, but it is always in a certain condition in the form of certain flow[4]. In this paper, the dispersion of the slurry is simplified, which is considered as the mainstream of the research work.

## 1. CEMENT SLURRY DIFFUSION MODEL

In the process of sealing the actual reservoir, the diffusion of cement slurry in the reservoir is determined by the grouting method, which is equivalent to the point source, and the slurry is spherical. When the pipe type grouting, the slurry is cylindrical diffusion. In this paper, the type of cement slurry seal is a pipe type grouting, cement slurry in the reservoir is a cylindrical distribution characteristics. When the cement slurry seal the reservoir, the viscosity of the slurry changes with the time, which causes the change of the permeability coefficient. According to Darcy's law[5]:

$$q=K_gAi. \tag{1}$$

Type: $q$ is a unit of time within the cement slurry flow rate, unit ($cm^3$/s); $i$ is the hydraulic gradient in the slurry, $A$ is a penetration section area, unit ($cm^2$); $K_g$ is the permeability coefficient of cement grout in the stratum, the unit (cm/s).

Assume the change law of permeability coefficient of cement slurry is[6]:

$$K_g = \frac{K}{\beta}e^{-\alpha t}. \tag{2}$$

Type: $K$ is the permeability coefficient of water in the formation, unit (cm/s); $\beta$ is the ratio of cement slurry viscosity and water viscosity; $\alpha$ is a parameter, which is related to the porosity of cement slurry and the reservoir; $t$ is the time of the slurry from the mixing to the test time, the unit (s).

Type

$$\alpha = A\frac{\tau_0}{\mu}\cdot\frac{d_m}{d_0}. \quad (3)$$

Type: $\tau$ is the ultimate shear stress of the slurry, the unit (N/cm$^2$); $\mu$ is the dynamic viscosity coefficient of the slurry, the unit (mPa·s); $d_m$ is the average diameter of the solid particles in the slurry, the unit (cm); $d_0$ is the average diameter of pores in the reservoir, and the unit (cm).

Grouting quantity with the change of grouting pressure:

$$Q = K_g(p_0 - p_R)\frac{2\pi a}{\ln(R/r_0)} = \frac{K}{\beta}e^{-\alpha t}(p_0 - p_R)\frac{2\pi a}{\ln(R/r_0)}. \quad (4)$$

Type: $Q$ is the instantaneous slurry flow rate, unit (cm$^3$/s); $p_0$ is the bottom pressure, the unit (kPa); $r_0$ is the radius of the grouting pipe, the unit (cm); $a$ is the thickness of the grouting layer, the unit (cm).

When the injection time and the pressure difference are known, the radius of T can be calculated as (5):

$$R = \sqrt{\frac{2(p_0 - p_R)K}{\bar{n}\ln(R/r_0)}\cdot\frac{K}{\beta}e^{-at}T}. \quad (5)$$

$R$ is the grouting radius of the $T$ moment, the unit (cm); $\bar{n}$ is the average porosity of the reservoir.

Because of the increase of the viscosity of the slurry in the actual grouting process, the average value of the viscosity of the slurry at every moment can be better reflected by the grouting parameters. Because the average value of the slurry viscosity as the grouting parameters of the method to consider the impact of the change of viscosity, so it is more reasonable. Using the integral method to obtain the average value of the viscosity of the slurry, and then deduced the calculation formula of the grouting radius and the time of the viscosity gradient type grout. Derivation of the formula for calculating the diffusion radius of grout in the viscosity gradient type grouting project. The average value of the viscosity of the gradient type slurry is equal to the sum of the value of each time and the total time divided by the time. That is[7]:

$$\bar{\mu} = \frac{\int_0^t \mu(t)\,\mathrm{d}t}{t}. \quad (6)$$

Type: $\bar{\mu}$ is the average value of the slurry viscosity, unit (mPa·s); $\mu(t)$ is a functional relation between the viscosity and the time of the slurry, and the unit (mPa·s); $t$ is the injection time, unit (s).

So there is

$$\beta = \frac{\bar{\mu}}{\mu_w} = \frac{\int_0^t \mu(t)\,\mathrm{d}t}{\rho_w v_w t}. \quad (7)$$

Type: $\rho_w$ is the density of water, unit (g/m$^3$); $v_w$ is the viscosity coefficient of water movement, unit (m$^2$/s).

The derivation of the viscosity gradient type slurry Equation (5) to obtain the grout diffusion radius formula is as follows:

$$r = \sqrt{\frac{2kh_1\rho_w v_w t^2}{n\ln\frac{r}{r_0}\cdot\int_0^t \mu_l(t)\,\mathrm{d}t}}. \quad (8)$$

## 2. SIMULATION OF FLOW LAW OF CEMENT SLURRY SEAL IN RESERVOIR

### 2.1 The Establishment of Physical Model

In this paper, the Comsol software is used to establish a single well layer, no production wells and water injection wells, and the isotropic of the formation of cement slurry seal solid model, the actual formation is simplified to a two dimensional model, which can effectively simulate the real features of some strata. The model is based on a single hole, and the hole is located on the left side of the pipe, the diameter is 0.2 m. Extend 2.5 m in the pores, the depth is 10 m, and establish a 5×10 m two dimensional model. As shown in Figure 1. After the model building grid, the entrance is optimized for processing and the mesh division at the entrance is encrypted, and the flow characteristics of the cement slurry in the strata are highlighted.

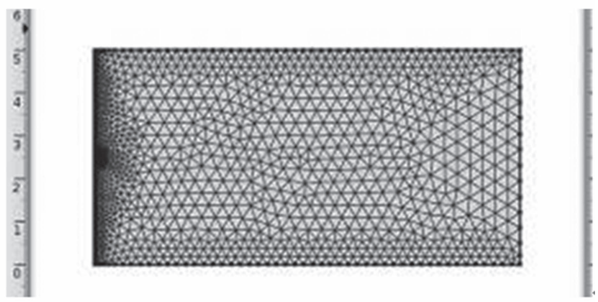


**Figure1**
**Two Dimensional Model of Cement Slurry Seal Reservoir**

 

### 2.2 Study on the Variation of the Diffusion Velocity of Cement Paste With the Time of Injection

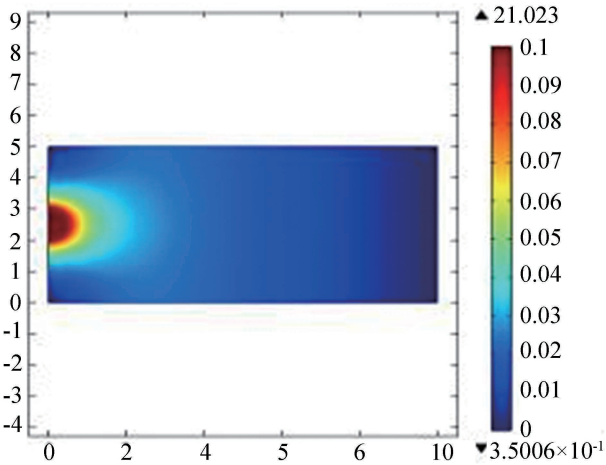


**Figure 2**
**The Distribution of the Cement Slurry Diffusion Velocity**

Set basic formation parameters, formation pressure is 4.4 MPa, formation permeability is 2.12×10$^{-3}$ μm$^2$, formation porosity is 0.21, cement slurry injection pressure is 6 MPa, cement slurry density is 1.9 g/cm$^3$, cement slurry incident aperture is 0.2 m, simulation of the change of the diffusion velocity of cement slurry with the injection time. The velocity distribution is shown in Figure 2, and the variation of velocity is shown in Figure 3.

The simulation results show that the diffusion velocity of cement slurry in the process of formation diffusion decreases sharply firstly, and then decreases with the increase of the diffusion distance. When the diffusion distance reaches 0.5 m, the diffusion velocity decreases slowly. When the cement slurry is injected between 0-30 min, the diffusion velocity varies greatly, when the injection time is over 30 min, the diffusion rate of cement slurry is small. With the increase of time, the gradient of the diffusion velocity of cement slurry is basically the same, and the diffusion distance has little change.

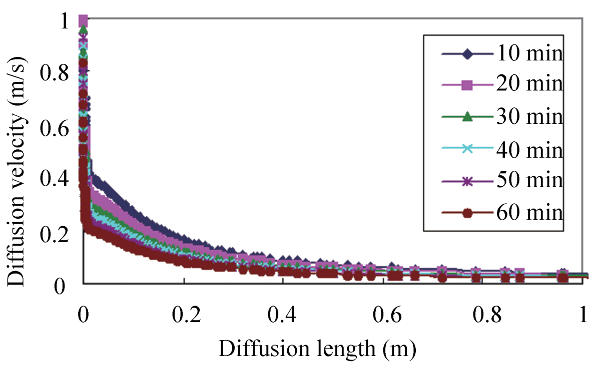


**Figure 3**
**The Change Law of the Cement Slurry Diffusion Velocity**

### 2.3 Study on the Variation Law of the Diffusion Velocity of Cement Paste With the Pressure of Injection

Set basic formation parameters, formation pressure is 4.4 MPa, formation permeability is 150×10$^{-3}$ μm$^2$, formation porosity is 0.18, cement slurry density is 1.9 g/cm$^3$, cement slurry incident aperture is 0.2 m, injection time is 30 min. Simulating the change of the diffusion velocity of cement paste with the injection pressure, whose speed variation law is shown in Figure 4.

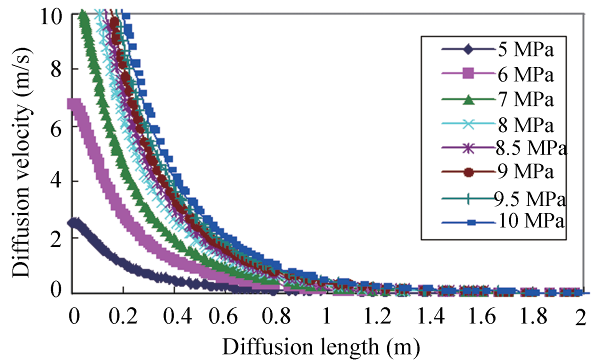


**Figure 4**
**The Change Law of the Cement Slurry Diffusion Velocity**

The simulation results show that under different injection pressures, the diffusion speed of the cement slurry increases with the increase of the injection pressure, the greater the pressure, the more the diffusion distance. However, the overall trend of the cement slurry diffusion rate is still the same, and it is the first to decrease slowly and then to lower the trend. When the diffusion distance reaches 0.5 m, the diffusion speed slows down, and when the diffusion distance is over 1.5 m, the diffusion velocity is zero and stop flow.

### 2.4 Study on the Variation of the Diffusion Velocity of Cement Paste With the Size of the Pore Size

Other simulation conditions are the same, and the 0.1 m - 0.6 m of the cement slurry in the formation is gradually increasing. Its speed variation is shown in Figure 5.

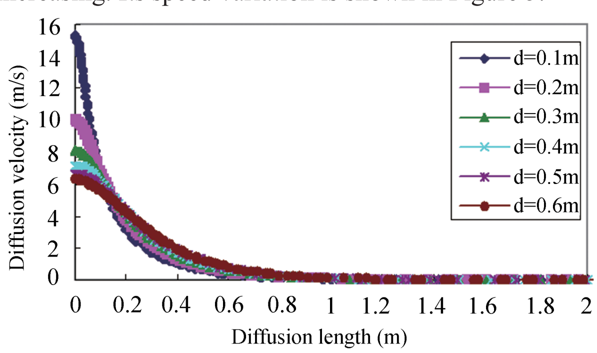


**Figure 5**
**The Change Law of the Cement Slurry Diffusion Velocity**

The simulation results show that under different incident aperture, the diffusion velocity of cement slurry decreases with the increase of the incident aperture, the larger the incident pore diameter is, the greater the injection flow rate is, the more obvious the sealing effect is. When the incident aperture is small, the initial diffusion velocity of cement slurry is relatively high, but the diffusion velocity decreases rapidly and the diffusion distance is shorter. When the incident aperture is large, the initial diffusion rate of cement paste is lower, but its diffusion speed is slow, and the diffusion distance is far away, it can achieve a good sealing effect.

## CONCLUSION

In the process of cement slurry sealing in the abandoned well, The diffusion velocity of cement paste decreases rapidly with the increase of diffusion distance. The diffusion velocity of cement slurry is reduced sharply after entering the formation, the diffusion speed of the cement slurry is decreased obviously after the diffusion distance of 0.5 m, the diffusion rate of cement slurry is obviously slowed down. After the diffusion distance of 1.5 m, the diffusion rate of cement slurry is zero, can be neglected.

Cement slurry injection time in 30 min is the best, less than 30 min cement slurry diffusion distance, sealing effect is poor, more than 30 min after the closure of the effect is less. Under the premise of not more than the formation pressure, the greater the injection pressure, the more obvious the diffusion effect, the farther the diffusion distance; But with the increase of the pore size, the amount of cement paste increases, the initial diffusion velocity decreases, but the diffusion distance becomes larger, and the sealing effect of the formation is improved.

## REFERENCES

[1] Hao, Y. Z. (2000). Determination and analysis of main rheological parameters of cement paste. *Water Conservancy and Hydropower Scientific and Technological Progress*, (40), 32-34.

[2] Sun, B. H., Gao, Y. H., & Liu, D. Q. (2007). Numerical simulation of annular flow and its flow degeneration of cement slurry. *Water Dynamics Research and Development*, *23*(3), 317-324.

[3] Zheng, Y. G., & Hao, J. F. (1995).Research on the movement law of cement slurry displacing mud in cementing slurry. *Western Exploration Engineering*, *7*(3), 29-31.

[4] Wang, J. Y., Li, X. Z., & Wang, L. Q. (2005). Development and application of the technology of filling and sealing of the discarded well. *Petroleum Machinery*, *33*(7), 55-58.

[5] Xu, B. H., Guo, X. Y., & Liu, C. J. (1996). Development and application of cement injection simulation system. *Journal of Southwest Petroleum University*, (3), 38-43.

[6] Mack, D. J., & Kendrick, D. (2003, September). *Low density, lost circulation control slurry utilizing a unique lcm allows successful, single-stage cementing of extremely long production intervals in the Appalachian basin*. Paper presented at SPE Eastern Regional Meeting, Pittsburgh, Pennsylvania, USA.

[7] Jones, P. H., & Berdine, D. (1940, January). *Oil-well cementing: Factors influencing bond between cementand formation*. Paper presented at Drilling and Production Practice, New York, USA.