The Analysis of Multiphase Lubrication and Related Properties

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Abstract—It is very difficult that experimental data collection was carried out in the small holes directly.And because of the rheological properties of non-newtonian fluid being complex, its transmission parameters in the channel, people often were depended on the single factor experiment chart or experience formula. so proper rheological model of holes was established when the large-scale pipeline transmission of multiphase mixture fluid rheological model and the research methods were drawn and combined with small hole transmission uniqueness.At last the simulation analysis on its rheological properties were studied. The experimental phenomena and results verify the rationality and effectiveness of the proposed model,which Provided a good theoretical basis to collect experimental data in the small holes directly.

Keywords-multiphase lubrication 、 rheological model 、 simulation

I. INTRODUCTION

The nstudy of Multiphase lubricating gel rheological in holes is a new topic, at present only a non-newtonian fluid (such as grease, coal-water slurry, oil polymer injection, etc.) in conventional pipeline research results were referenced (1-5). And because of the rheological properties of non-newtonian fluid being complex, its transmission parameters in the channel, people often were depended on the single factor experiment chart or experience formula of the [6], and the references on theoretical model of non-newtonian fluid channel and its characteristics were very few. The experimental phenomena and results verify the rationality and effectiveness of the proposed model,which Provided a good theoretical basis to collect experimental data in the small holes directly .

It is often desired to mathematically simulate the flow of fluids through porous materials in order to design processes, and to make decisions regarding the operation and control of processes. Many of the issues regarding modeling flow in porous media are the same regardless of the application, and candidate mathematical descriptions are available for many applications.

From a fluid mechanics point of view, there is an expectation that new functional materials are to be created in terms of controlling the microstructure of a colloidal dispersion in a nonequilibrium magnetic, electric, or flow field. Hence, the clarification of dynamics on the necessity of ferrofluid flowing through porous materials is highly important.

In the paper proper rheological model of holes was established when the large-scale pipeline transmission of multiphase mixture fluid rheological model and the research methods were drawn and combined with small hole transmission uniqueness.At last the simulation analysis on its rheological properties were studied(6-8). The experimental phenomena and results verify the rationality and effectiveness of the proposed model,which Provided a good theoretical basis to collect experimental data in the small holes directly(9-16).

II. THE ANALYSIS OF MULTIPHASE LUBRICATING GEL PERFORMANCE IN THE HOLE

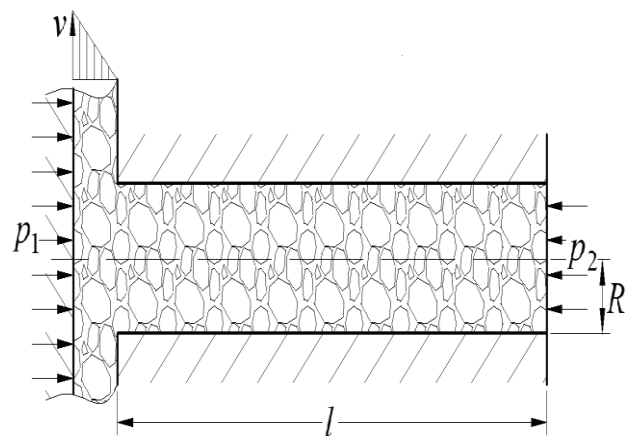Multiphase lubricating gel in the hole stress distribution was showned as Fig .1.

Figure 1. Force analysis of multiphase lubricating gel in the hole

Channel of lubricating gel in the process of high speed sliding would produce a differential pressure due to the friction thermal effect and the migration effects of colloid. If the differential pressure is large enough colloid would generate directional flow in channel according to the principle of PASCAL and alveolus capillary effect.so the first condition of colloid flow in the hole was pressure difference on both ends of the channel

The driving force of colloid on column face can be expressed as follows:

$$F_{\mathrm{d}} = (p_1 - p_2) \cdot \pi R^2 = \Delta p \cdot \pi R^2$$

（1）

Δp ---- Differential pressure at the ends of the channel (Pa),

R ---- Hole radius $(\mu\mathrm{m})$。

τ_y $(\mathrm{N}/\mu\mathrm{m}^2)$ was the per unit area yield stress between Colloid layer,(τ_y was influenced by colloid viscosity, the adsorption function between colloid and hole wall and the hole wall surface roughness, etc), the flow resistance whose radius was r the hole in the gel column was obtained as:

$$F_r = \tau_y \cdot 2\pi r \cdot l \qquad (0 \le r \le R, \qquad 0 < l \le L)$$

（2）

l ---- Gel column length of channel，$(\mu\mathrm{m})$。

So to achieve full shear flow within the channel, the conditions must be satisfied:

$$F_d > F_r$$

（3）

By substituting Eqs. (1), (2) in Eq. (4), the following formula wae obtained:

$$f(\Delta p, R, L, \tau_y) = F_d - F_r = \Delta p \cdot \pi R^2 - \tau_y \cdot 2\pi R L > 0$$

Obviously, τ_y was the greater the mobility within the hole was the better, and the flow resistance is proportional to the

III. THE TRANSMISSION MODEL OF MULTIPHASE LUBRICATING GEL IN THE CHANNEL

From the above analysis, the colloid flow in channel was composed of three parts, namely:

$$Q_t = Q_c + Q_d + Q_s$$

(4)

Q_t ---- The total colloid capacity of channel $(\mu\mathrm{m}^3/\mathrm{s})$；

Q_c ---- The colloid flow caused by a plug flow in channel $(\mu\mathrm{m}^3/\mathrm{s})$；

Q_d ----The Colloid flow caused by the gradient flow in channel $(\mu\mathrm{m}^3/\mathrm{s})$；

Q_s ---- The colloid flow caused by wall slip in channel $(\mu\mathrm{m}^3/\mathrm{s})$；

The total flow equation of colloid in the channel can be obtained：

$$Q_t = \frac{\pi \cdot v_s \cdot R^2}{3}\left[(\frac{3}{2} - x_2)^2 + \frac{3}{4})\right] + \pi \cdot v_c \cdot R^2 \cdot (1 - x_2)^2$$
$$- \frac{\pi \cdot \tau_w' \cdot R^3}{1 - x_1 - x_2} \cdot \left[\frac{(1-x_2)^4}{4} - \frac{2 \cdot x_1 \cdot (1-x_2)^3}{3} + \frac{x_1^2 \cdot (1-x_2)^2}{2} - \frac{x_2^4}{12}\right]$$

(5)

The average flow velocity equation can be calculated as following:

$$\overline{v} = \frac{Q_t}{\pi \cdot R^2} = \frac{v_s}{3}\left[(\frac{3}{2} - x_2)^2 + \frac{3}{4})\right] + v_c \cdot (1 - x_2)^2$$
$$- \frac{\tau_w' \cdot R}{1 - x_1 - x_2} \cdot \left[\frac{(1-x_2)^4}{4} - \frac{2 \cdot x_1 \cdot (1-x_2)^3}{3} + \frac{x_1^2 \cdot (1-x_2)^2}{2} - \frac{x_2^4}{12}\right]$$

(6)

IV. MODEL VALIDATION AND DISCUSSION

Based on the model of the Multiphase lubricating gel flow in the hole ,the simulation figure on average flow velocity within the channel influenced by different wall slip layer thickness, different plug flow diameter and hole radius would be showed as following:
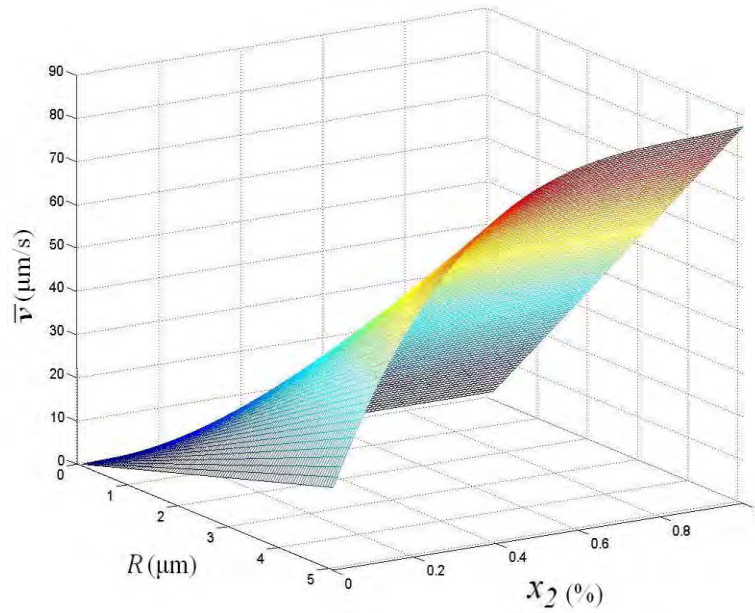
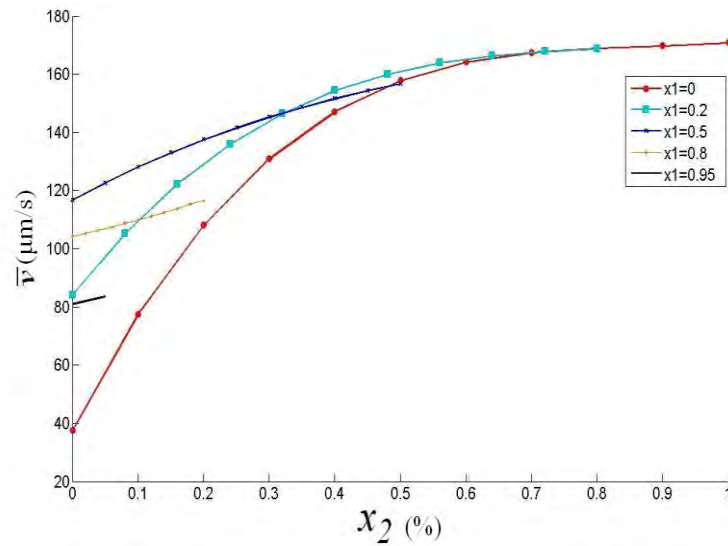Figure 2. The influence of average flow velocity $\bar{v}$ by layer thickness Δ and hole radius R

Figure 3. The colloid average flow velocity curve affected wall slip layer thickness

Showed as the Fig .2, during the gradient flow , the radius of tunnel was the smaller, the flow of the mixed colloid was more difficult, but the emergence of wall slip can effectively improve the mobility of the colloid.

When mixed colloid flowed in the channeltunnel,with determined radius 、 different composition 、 viscosity 、 different temperature and pressure, wall slip layer are different.The colloid average flow velocity curve affected wall slip layer thickness could be obtained as Figure 3.

It was Clearly unwise to improve its liquidity in the hole through the lower the viscosity of the gel, the reason were two parts: on the one hand, the radius of plug flow was the smaller, the proportion of colloid by the shearing action of saponification fiber was the greater, and the situation of the separation of producing phase drift and components were the worse .The colloid stability in the state of the rheological properties and tribological properties would change at the same time,;, on the other hand,it was very limited to improve its liquidity in hole that the colloid viscosity was reduced . regardless of the wall slip effect, when the radius of the plug flow layer $r^* \approx 6\mu m$, colloid velocity in the channel was max;When plug flow layer radius $r^* = 0\mu m$, flow rate

was min, and maximum value was only about 2.2 times of its minimum value.

IV. CONCLUSIONS

The model of polyphase lubricating gel when going from the bionic cell body was established in the paper. According to the discussion of the model equation and numerical simulation analysis, the main conclusions were as follows:

1）The slip layer whose viscosity significantly reduced ,which would cause colloid additional velocity ,would be produced near the side wall in the hole when Multiphase lubricating gel non-uniformly flowied in the channel .It would help to improve liquidity within the channel

2）With the same radius of plug flow layer, the hole in the wall slip layer was thicker, the effect on the improvement of the colloid liquid was the more obvious. But it was unwise to improve its liquidity in hole through lowering the colloid viscosity, and the effect was limited.

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