ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 8, Issue 1 , January 2021

Prevention of Drilling Mud Filtrate Inflow into Formation Pores by Regulating Rheological Properties of Flushing Fluids

RaupovAnvarAbdirashidovich

PhD in Technical Sciences, Head of Strategic Planning and Energy Security Department of the Ministry of Energy of the Republic of Uzbekistan, Republic of Uzbekistan. Tashkent

ABSTRACT: The paper studies the composition and properties of plugging materials used to prevent the flow of the mud filtrate into the pores of the reservoir. In order to successfully perform colmatation works it is recommended to use such fluids, which have additional resistance to flow in a porous medium. Polyacrylamide (PAA) was used as a high-molecular-weight, high-elastic polymer.

Experimental studies obtained the dependence of the tangential stress on the velocity gradient for PAA solutions of different concentrations. It is confirmed that the character of flow is determined by elastic properties of polymers and interaction of polymer with wellbore wall. In order to provide evenly the formation bridging it is recommended to use such drilling muds with bridging, as well as chemical reagents that have the ability to decrease the rock permeability due to adsorption and mechanical capture of polymers by the rock.

KEY WORDS: rheology, liquid, solution, chemical reagents, dependence, viscosity, elastic properties, polymer

I. METHODOLOGY

Qualitative opening of depleted formations to a large extent depends on the type and composition of flushing fluids and their rheological properties. At present the most widespread flushing fluids are clay solutions treated with various chemical reagents. It is well known that washing and plugging fluids do not behave the same way as Newtonian fluids during deformation. They have more complex structural and mechanical properties. That is why their behavior cannot be described only by the viscosity coefficient. In addition to viscous, they have plastic and elastic properties inherent to solids. Rheological parameters of flushing fluids and their control are of great importance during drilling-in and formation opening with ANPD, i.e. while determining pressure in various circulating systems and in annulus. When using flushing fluids with viscoplastic properties one may determine the depth of fluid penetration by the formula

$$l = \frac{\Delta P_0 \cdot \sqrt{k}}{\alpha \cdot \tau_0}, \qquad (1)$$

where ΔP_0 - is pressure drop in the case of limit equilibrium; α - constant; τ - limit shear stress. The expression for the pressure drop can be represented as

$$\Delta P = 0{,}1 \cdot \rho \cdot h + \frac{2 \cdot \tau_0 \cdot H}{R_0 - R_{ck}}, \qquad (2)$$

where ρ - density of flushing fluid; h - depth of occurrence of absorbing formation; R_0 and R_{ck} - well and drill string radii, respectively.

N.V. Tyablin got the following formula for determination of pressure drop during viscoplastic fluid filtration

$$\Delta P = \frac{3 \cdot Q \cdot \eta \cdot R_k}{4 \cdot \pi \cdot h^3 \cdot R_c} + \frac{3 \cdot \delta_0 \cdot (R_k - R_c)}{2 \cdot h} \qquad (3)$$

where, R_k and R_c - radii of the spreading contour and borehole, respectively; h - opened fractures.

In [1] the dependence of pressure drop and viscoplastic fluid flow rate with regard to inertial motion is obtained

$$\Delta P = \frac{3 \cdot Q \cdot \eta}{4 \cdot \pi \cdot h^3} \ln \frac{R_k}{R_c} + \frac{3 \cdot \delta_0 \cdot (R_k - R_c)}{2 \cdot h} - \frac{\bar{\rho}(R_k^2 - R_c^2)Q^2}{32\pi^2 h^2 R_c^2 R_k^2} \qquad (4)$$

Formulas (1), (2), (3), (4) show that with the increase of ultimate shear stress 0, the depth of flushing fluid penetration into formation is slightly decreasing, but the pressure on formation is significantly increasing. As the depth increases, this relationship will increase. Therefore, increasing the ultimate shear stress in order to prevent fluid filtration is ineffective.

The use of plugging materials with high plastic properties causes the necessity of creating a large pressure drop on the reservoir [2]. In this case, colmatants penetrate into the formation mainly through channels with large effective cross-sections, while channels with small cross-sections are not filled with occluding material.

Moreover, in the channels with large cross-sections, the ultimate equilibrium occurs at a much greater penetration depth, which leads to the formation of tongues of their solidified mixture in the formation, i.e. to non-uniform filling of the casing zone with the mixture. Thus, for successful colmatation works it is necessary to use such fluids, which have additional resistance during movement in porous medium. Solutions of high molecular weight polymers have such properties. The movement of polymer solutions in porous media is accompanied by some characteristic phenomena: effects typical of Newtonian fluids, reduction of permeability, and polymer adsorption. In terms of rheological properties the flow of the solution can be dilatant at some shear rates, so with the increase in the shear rate the resistance to shear increases.

II. CALCULATION RESULTS

It is noted in [3] that viscoelastic fluids are effective drilling fluids for high porosity formations. When pumping such fluids in the annular space there are low resistances, and simultaneously these fluids have high viscosity during the movement in the narrower parts of the filtration channels. Thus, the intensity of fluid inflow into the reservoir is reduced due to both high resistance to fluid movement in the reservoir and reduced pressure on porous reservoir.
In this regard, we have conducted a series of experimental studies on the filtration of viscoelastic fluid solutions in a porous medium. Polyacrylamide (PAA) was used as a viscoelastic polymer. The rheological properties of these polymers were investigated with a capillary viscometer. Five PAA solutions of different concentrations in distilled water were studied in the range of rate gradient measurements from 2 sec-2 to 5600 sec-1.

For all solutions the dependences of the pressure drop ΔP on the flow rate Q were taken. The rate gradient was determined by the formula

$$V = \frac{4 \cdot Q}{\pi \cdot R^3} \qquad (5)$$

and corresponding tangential stress

$$\tau = \frac{\Delta p R}{2l} \qquad (6)$$

The results of the experiments are presented in the graphs of Fig. 1.

Fig. 1 shows that at low PAA concentrations the dependence of the velocity gradient on the shear tangential stress is close to the Newtonian character of the flow. As the concentration of the solution increases, the rheological curves look like a power law of flow (Ostwald-de Wahl power law). Thus, at high concentration we obtain non-linear rheological curve.

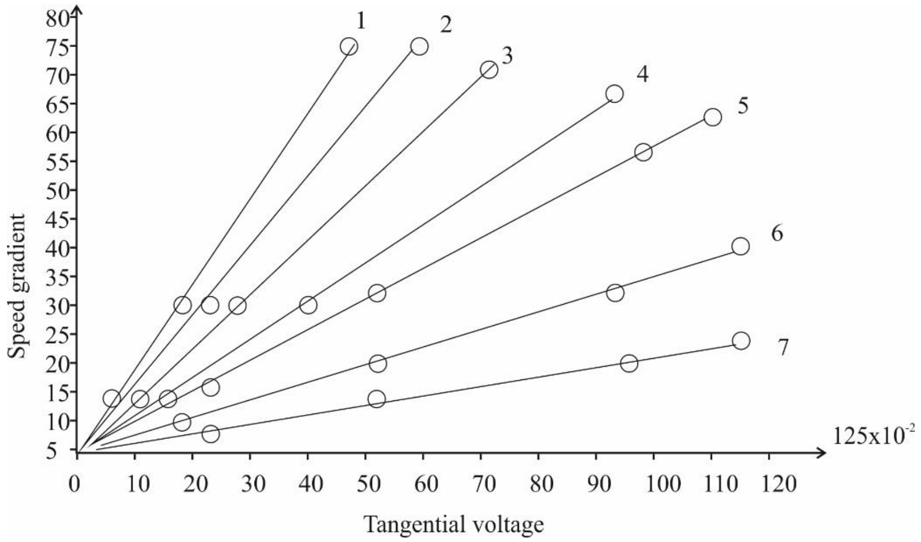

Fig. 1. Dependence of tangential stress on velocity gradient for PAA solutions of different concentrations 1 – 0,001%; 2 – 0,0015%; 3 – 0,003%; 4 – 0,006%; 5 – 0,01%; 6 – 0,03%; 7 – 0,07%.

Further studies were carried out on filtration of dilute polymer solutions in a porous medium. Note that the filtration process of a viscoelastic fluid in a porous medium differs significantly from the filtration of a Newtonian fluid. The first series of experiments was carried out in an artificial uncemented porous medium with permeability K = $0.38.10^{-12}$ m^2 at temperature t = 25°C. The fluid under study was a 0.07% solution of PAA polymer prepared in fresh water. After the porous medium was saturated with PAA solution, continuous liquid flow rate was measured in time at differential pressure P = $1.001x10^5$ Pa until the steady-state regime was established. The results of the experiments are shown in Fig. 2.

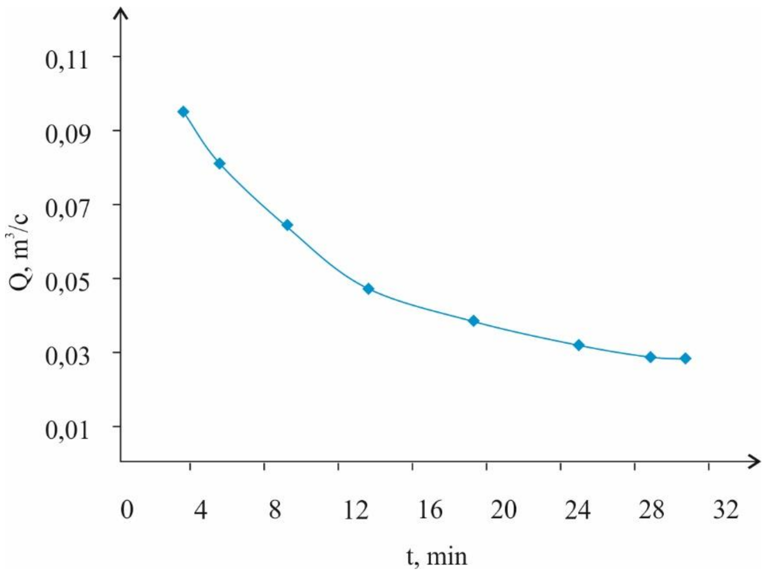

Fig. 2. Filtration of dilute 0.07% PAA solutions in porous medium

The results of the performed experiments show that during visco-elastic liquids filtration in porous medium at constant pressure drop, the filtration flow rate does not remain constant in the course of the experiment, but gradually decreases until it reaches the steady value. At the same time, the setting time of filtration flow rate was of the order of several hours.

Thus, PAA polymer solution leads to the increase of resistance during its movement in porous medium. The additional resistance along the length of the porous medium is caused by the penetration along its length of the PAA molecule in sizes that approach the size of the pore channels.

Note that there are different opinions on the explanation of the filtration and rheological features of polymer solutions. Thus, analysis of the experimental results shows three mechanisms of permeability reduction during filtration of polymer solutions: adsorption, helium formation and formation pore clogging.

Analyzing the results of research to identify the mechanism of filtration of model Newtonian liquids and polymer solutions, Gogarty W.B. [3] draws a conclusion about permanent reduction of core permeability during filtration. The permeability decrease is explained both by polymer adsorption in the porous medium and by mechanical trapping of polymer associates by pores which are smaller than these particles. In this case, there is a clogging of smaller pores and their inclusion from the filtration process. He proposes the following mechanism of polymer solutions filtration in porous media: up to the velocity of 3 m/day the rheological dependence of the solution viscosity on the velocity gradient has a prevailing effect on the flow character. At higher filtration speeds, when the rheological viscosity change is less dependent on the speed, elastic properties of polymer particles begin to dominate, which leads to an increase in the viscosity effect, and thus to a decrease in the mobility of polymer solution.

Based on his experiments on filtration of polymer polyox (polyethylene oxide) solutions, Daufen D.Y. [4] concludes that the high co-cross flow of polyoxane solutions in a porous medium is explained by the joint effect of polymer interaction with the pore walls and viscoelastic effects. The interaction of polymers with the walls of pores causes the loss of part of the kinetic energy and is expressed in anomalously high flow resistance. The macromolecule deforms under the action of stresses, and normal stresses arise, the size of which causes viscosity anomalies.

Experimental data obtained by Harvey A.H. are of great interest. [5], in the filtration of solutions of polysaccharide, polyox and polyacrylamide. Solutions prepared in distilled water with concentrations ranging from 0.25% to 0.10% were filtered through a bulk porous medium consisting of glass hinges. These experiments were conducted at a constant flow rate. Significant differences were found in the flow patterns of polysaccharide, polyox and polyacrylamide solutions. The polysaccharide solutions behaved mainly as normal non-Newtonian fluids (their flow character is described by Ostwald's power law). The behavior of polyox solutions deviates from that of a normal non-Newtonian fluid toward an abnormally high decrease in mobility with increasing velocity (dilatant flow).

Therefore, it can be stated that the dilatant flow pattern is determined by two factors: elastic properties of polymer solutions and polymer-wall interaction.

Consequently, polymer solutions may behave in a porous medium in different ways, exhibiting pseudo-plasticity, dilatancy and Newtonian fluid properties.

In this connection, let us consider the influence of pseudoplastic and dilatant properties of the plugging mixture on the character of flow in the flat slit. We will take Ostwald De Vall model as a rheological model of fluid

$$\tau = k\left(\frac{dv}{dr}\right)^n \qquad (7)$$

where τ - shear tangential stress, k - fluid consistency index. If $n = 1$ - Newtonian fluid; $n < 1$ - pseudoplastic fluid, $n > 1$ - dilatant fluid. The calculation scheme in cylindrical system of coordinates is shown in Fig. 3.

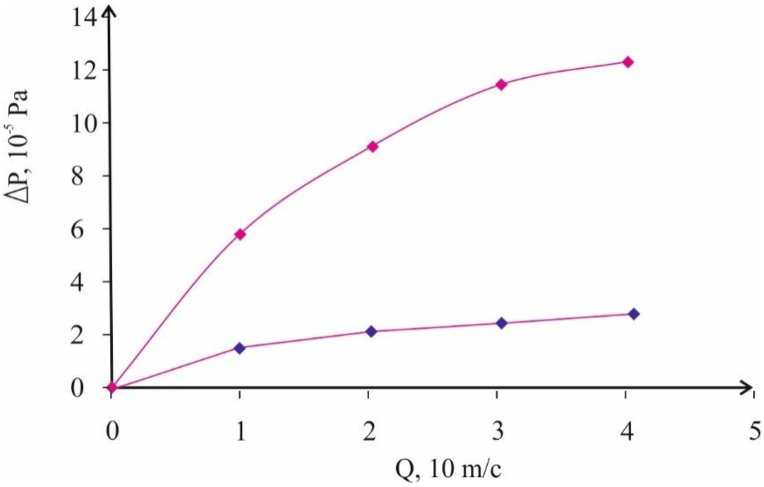

Fig. 3. Dependence of the indicator line on pseudoplasticity

1 - n = 0,4; 2 - n = 0,6

For elementary volume of liquid in the slot for tangential shear stress we can write

$$\tau = -\left(\frac{\partial P}{\partial r} + \rho\frac{dV}{dt}\right)Z \qquad (8)$$

Combined integration of equation (7) and (8) and considering $V = 0$ at $Z = h$ gives

$$V = \sqrt[n]{-\frac{\partial P}{\partial r} + P\frac{dV}{dZ}}\frac{n}{(i+n)K^{\frac{1}{n}}}\left(h^{\frac{n+1}{n}} - Z^{\frac{n+1}{n}}\right) \qquad (9)$$

Let's define the liquid flow rate through the cross section of radius r

$$Q = 4\pi r\int_0^h VdZ \qquad (10)$$

Substituting (9) into (10), after integration and transformation we obtain expression for fluid flow

$$Q = \sqrt[n]{-\left(\frac{\partial P}{\partial r} + \rho\frac{dV}{dt}\right)}\frac{4\pi r(2+n)h^{\frac{n+1}{n}}}{(1+2n)(1+n)K^{\frac{1}{n}}} \qquad (11)$$

To find the pressure drop ΔP , let's find the acceleration $\frac{dV}{dt}$.

From the continuity equation we have

$$V_{cp} = \frac{Q}{4\pi hr} \qquad (12)$$

By differentiating (12) we obtain the formula for acceleration from the condition of certainty of velocity over the cross section

$$\frac{dV}{dt} = \frac{\partial V}{\partial r}V = -\frac{Q^2}{16\pi^2h^2r^3} \qquad (13)$$

Then from (11) we obtain

$$-\frac{\partial P}{\partial r}=\left[\frac{K^{\frac{1}{n}}(1+n)(1+2n)}{4\pi n(2+n)}\frac{Q}{n^{\frac{2n+1}{n}}}\right]^{n}\frac{1}{2n}-\frac{\rho Q^{2}}{16\pi^{2}h^{2}r^{3}}, \tag{14}$$

By integrating (14) over the finite values of R_e and R_u we obtain $(n = 1)$

$$\Delta P=\frac{K}{(1-n)h^{2n+1}}\left[\frac{(1+n)(1+2n)}{4\pi n(2+n)}\right]^{n}\left(R_k^{1-n}-R_c^{1-n}\right)\frac{\rho Q^{2}(R_k^{2}-R_c^{2})}{32\pi^{2}h^{2}R_k^{2}R_u^{2}} \tag{15}$$

In particular, for $n = 1 (K = \eta)$ we obtain solution for viscous fluid

$$\Delta P=\frac{3\eta Q}{4\pi h^{3}}\ln\frac{R_k}{R_c}-\frac{\rho Q^{2}(R_k^{2}-R_c^{2})}{32\pi^{2}h^{2}R_k^{2}R_u^{2}} \tag{16}$$

Results of numerical calculations based on formula (15) are shown in fig. 4.

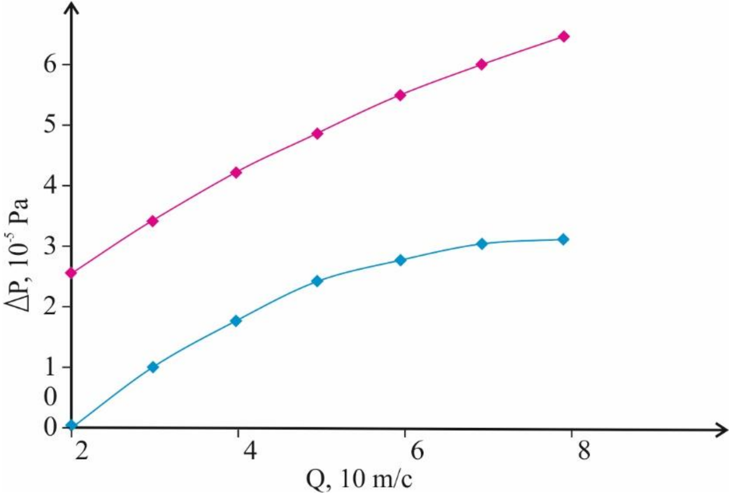

Figure 4. Pressure changes as a function of fluid flow rate

Also, for comparison, the calculated data for a viscoplastic fluid at $\tau_0 = 14$ Pa.

n1=0.4	q=0.001	p=1596.883	n1=0.6	q=0.002	p=2680.002
n1=0.4	q=0.0015	p=1878.06	n1=0.6	q=0.0025	p=515.9971
n1=0.4	q=0.002	p=2107.099	n1=0.6	q=0.003	p=-2504.931
n1=0.4	q=0.0025	p=2303.822	n1=0.8	q=0.001	p=20315.08
n1=0.4	q=0.003	p=2478.115	n1=0.8	q=0.0015	p=26781.96
n1=0.6	q=0.001	p=5777.858	n1=0.8	q=0.002	p=31938.45
n1=0.6	q=0.0015	p=7369.221	n1=0.8	q=0.025	p=35949.67
n1=0.6	q=0.002	p=8757.594	n1=0.8	q=0.003	p=38907.74
n1=0.6	q=0.0025	p=10012.23	n1=0.4	q=0.0001	p=620.5364
n1=0.6	q=0.003	p=11169.65	n1=0.4	q=0.00015	p=713.4826
n1=0.8	q=0.001	p=21834.48	n1=0.4	q=0.0002	p=778.0756
n1=0.8	q=0.0015	p=30200.61	n1=0.4	q=0.00025	p=822.2058
n1=0.8	q=0.002	p=38016.04	n1=0.4	q=0.0003	p=849.8095
n1=0.8	q=0.0025	p=45445.9	n1=0.6	q=0.0001	p=1436.138
n1=0.8	q=0.003	p=52582.32	n1=0.6	q=0.00015	p=1816.878
n1=0.4	q=0.001	p=77.4845	n1=0.6	q=0.0002	p=2139.033
n1=0.4	q=0.0015	p=-1540.586	n1=0.6	q=0.00025	p=2419.997
n1=0.4	q=0.002	p=-3970.493	n1=0.6	q=0.0003	p=2668.943
n1=0.4	q=0.0025	p=-7192.414	n1=0.8	q=0.0001	p=3445.338
n1=0.4	q=0.003	p=-11196.47	n1=0.8	q=0.00015	p=4752.288
n1=0.6	q=0.001	p=4258.46	n1=0.8	q=0.0002	p=5964.365
n1=0.6	q=0.0015	p=3950.576	n1=0.8	q=0.00025	p=7107.731

III. CONCLUSION

As can be seen from Fig. 4, the use of colmatation materials with high plastic properties causes the necessity of creating a large pressure drop in the reservoir. In this case colmatants penetrate into the formation mainly through the channels with large effective cross-sections, while channels with small cross-sections appear to be unfilled with colmatant, which leads to uneven purchase of near-bottom and inside the formation zone. That is why in order to perform successful formation pore bridging one should use flushing muds with colmatants as well as chemical agents, which are capable of reducing rock permeability due to rock adsorption and mechanical polymer entrapment by rock.

REFERENCES

[1] Movsumov A.A., Mamadjanov U.D. et al. Hydrodynamics of well intervention in complicated conditions. -Tashkent: 1972. –C. 286.
[2] Krysov V.I., Kretsul V.V. Influence of drilling mud repression and time of contact with rocks on its filtration properties / / Construction of oil and gas wells on land and at sea. - – M.: 2005, №1. –C. 35-41.
[3] Gogarty W.B. Pheslodicobpropertos of psewdopeastik fluids in po-rous media/"Soc. Petrol. J" 1972, №2. –P. 7.
[4] Daufen D.Y., Menzic D.E. Flow of polymer solutions through porous media. "J. Petrol Technol", No.8, 1967.
[5] Harvey A.H., Menzil D.G. Polymer Solution flow in porous media," Soc. petrol Eng. J.", June, No. 2, 1970. –P. 195.

AUTHOR'S BIOGRAPHY

Raupov Anvar Abdirashidovich- PhD in Technical Sciences, Head of Strategic Planning and Energy Security Department of the Ministry of Energy of the Republic of Uzbekistan.
Field of activity - drilling and development of oil and gas wells in difficult conditions.
Has more than 30 scientific publications in republican and foreign scientific and technical journals and conferences, 2 teaching aids for students