Geylani M.PANAKHOV, Gulshan R. AGAEVA

RESEARCH OF NONEQUILIBRIUM PROPERTIES OF INSULATING MATERIALS

Abstract

In the presented paper results of researches according to nonequilibrium properties of gaseous isolation systems applied to regulation of hydrodynamic bahavior of grouting mortar in "oil well-layer" system are shown. Aeration processes of isolating structures by means of gas-yielding agents additives are studied.

It is established, that isolation of thief formation is reached as a result of saturation of channels and fractures by aerated grouting mortar showing nonequilibrium properties in " oil well-layer".

In a quite number of technological systems on a basis of insulating water solutions showing relaxation properties, the nonequilibrium effects described by duration of transients are observed. Nonequilibrium properties of such systems can render significant influence on hydrodynamical behaviour of gas insulating solutions in system "oil well-layer". In this connection research and estimation of these properties of backfill systems is of practical interest.

At diagnosing relaxation properties of insulating solutions the following method [1, 2, 3] has been used. After flushing the researched solution in capillary (fig. 1) the coefficients describing viscous and plastic properties of solution are defined by received dependence "$Q - \Delta P$". Then capillary is filled by the researched solution under pressure and the gate at outlet of capillary is overlaped. Observing change in the system during pressure recovery process, relaxation time is calculated:

$$\ln \frac{P_\infty - p\,(t)}{P_\infty - p\,(0)} = a_1 t - a_2; \qquad a_2 = \frac{Tb\Delta pa}{4a} \tag{1}$$

where $p\,(t)$ is current pressure; $p\,(0)$ is pressure in the system at the beginning of experiment; p is pressure in the system at the end of experiment; t is current time; T is time of relaxation.

In fig. 2 curves of pressure recovery for initial grouting mortar solution (p_1, p_2) and gassy $\left(p_1^1, p_2^1\right)$ solution obtained by processing initial solution of calcium carbonate $CaCO_3$ (8 % from lump) and acidic water - pseudoboiling gaseous medium is obtained as a result of reaction of $CaCO_3$ with acidic water are represented.

Processing of curves p_2, p_2^1 by the formula gives the following values of relaxation times: $T = 400s$ for initial solution and $T^1 = 850s$ for aerated one.

Lag of pressure curve P_2 at outlet of capillary from the curve P_1 at inlet also characterizes relaxation properties of solution.

Definition of relaxation times during lag of the curve P_2 from the curve P_1 gives $T = 500s$ and $T^1 = 1400s$. It says that nonequilibrium properties of aerated solutions appear multiply more strongly, that should affect on hydrodynamical behaviour of solutions. The stronger nonequilibrium properties of such solutions, the less of pressure loss at its flow.

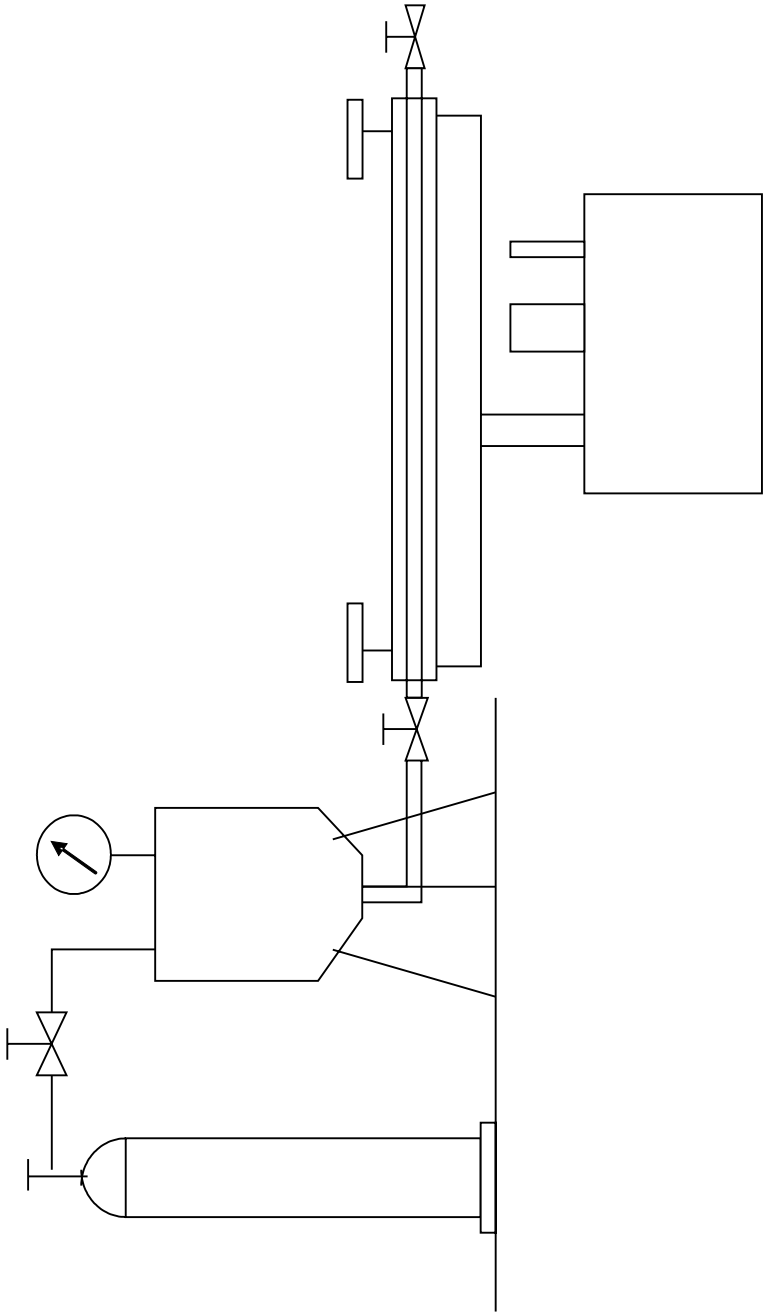

Fig. 1. Circuit of experimental installation for studying relaxation properties of fluids

Nonequilibrium properties of insulating solutions can be estimated also by Cross method whose essence is the representation of connection between shearing stress τ and effective viscosity μ in graphic form in coordinates $\left(1/\mu_{\acute{y}}^2 - \tau^2\right)$ according to rotary viscosimetry data. By the form of the curve we conclude about rheological properties of the researched solution: the sections parallel to abscissa axis $\left(\tau^2\right)$ correspond to viscous flow, other cases correspond to appearance of linear or nonlinear viscoelastic properties.

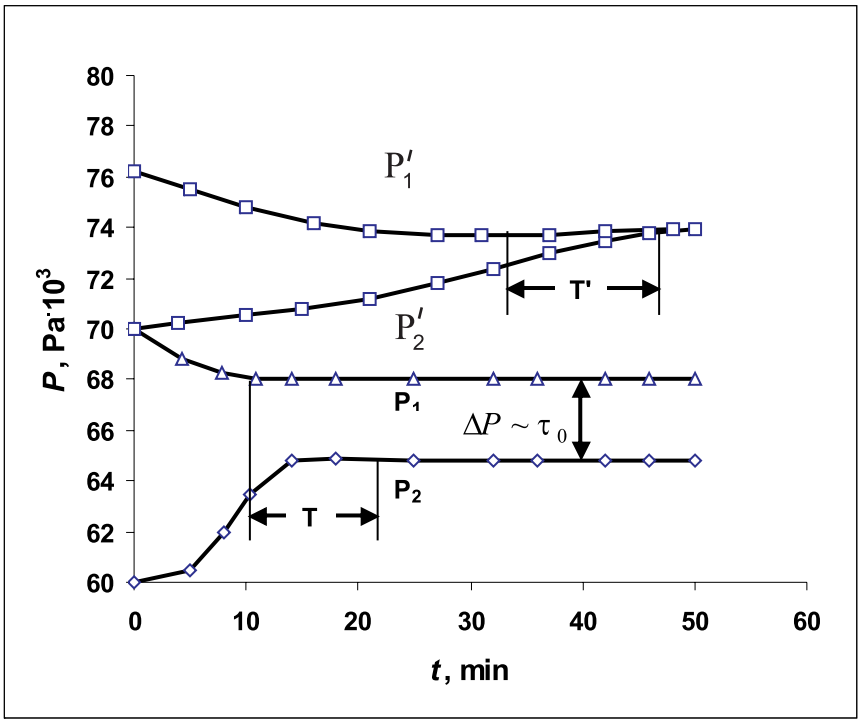

Fig. 2 Curves of pressure recovery in a capillary

Here, the slope angle of curve is inversely proportional to the square of the elasticity modulus of opening G.

In fig. 3 and 4 the corresponding dependences $\left(\frac{1}{\mu_{\acute{y}}^2} - \tau^2\right)$ constructed on data of rotational and capillary viscosimetry for solutions whose hydrodynamical behaviour during tests typically differed, are represented.

On the base of the received dependences we can conclude, that nonequilibrium properties of the researched solutions appear variously depending on shear rate γ . So, for non aerated solutions we can allocate three areas of flow: viscous at small shear rates $\left(\gamma < 160\ s^{-1}\right)$, linear-viscoelastic at shear rates from 160 up to 20000 s^{-1} and viscous at the big shear rates $\left(\gamma > 20000\ s^{-1}\right)$.

Viscoelastic properties of grouting mortar depend also on componental structure of water systems. At grouting mortar containing calcium carbonate $CaCO_3$ and water with high value of acidity, as one of the components practically in all range of shear rate it is observed nonlinear viscoelasticity whose character sharply varies at

shear rate greater than $20000s^{-1}$. At that it is observed reduction of magnitude $1/\mu_{\acute{y}}^2$ with growth of τ^2 and, hence, with growth of shear rate that says on dilatancial character of solutions flow . Probably, it occurs because stress in grouting mortars at the certain shear rate reaches some limiting value at which solution as the disperse system passes to new quality. Probably, it is connected with destruction and dispersion of air bubbles due to that there is an increasing of system volume, that requires expenditure of additional energy, and this is observed as growth of effective viscosity.

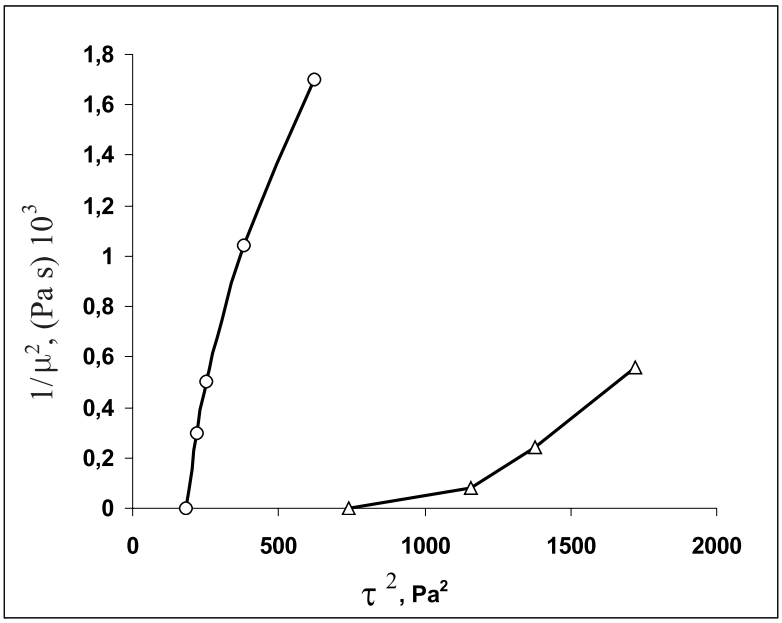

Fig. 3 Processing of results of rotational viscosimetry by Cross method

As the module of elasticity G is connected with relaxation time by the expression $T = \dfrac{\mu_{\acute{y}}}{G}$, we can define indirectly the relaxation properties of researched solutions to slope angle of curves $\left(1/\mu_{\acute{y}}^2 - \tau^2\right)$. In this case definition of relaxation properties by graphs cited in fig. 4 qualitatively agrees with the results received in capillary.

Nonequilibrium properties of solutions may be effectively used in intake beds. At that if intake occurs on cracks of collector then by giving dilatancial properties solution at high shear rate as it is shown above, we can achieve essential growth of hydrodynamics resistance in absorbing channels. If intake occurs in the porous medium, intensity of intake of a viscoelastic solution can be defined from the following expression [4-7]:

$$q = \frac{2\pi kh}{\mu} p_0 \frac{2Tx^2}{2T_0 x^2 \ln x + T}$$

where k is permeability of bottom hole zones of intake bed;

h is bed thickness;

μ is slurry viscosity;

P_0 is repression on intake bed;

$T_0 = r_c^2/4æ$;
r_c is radius of hole;
æ is piezoconductivity of bed;
$X = \dfrac{R(t)}{r_c}$;
$R(t)$ is the current radius of input zone.

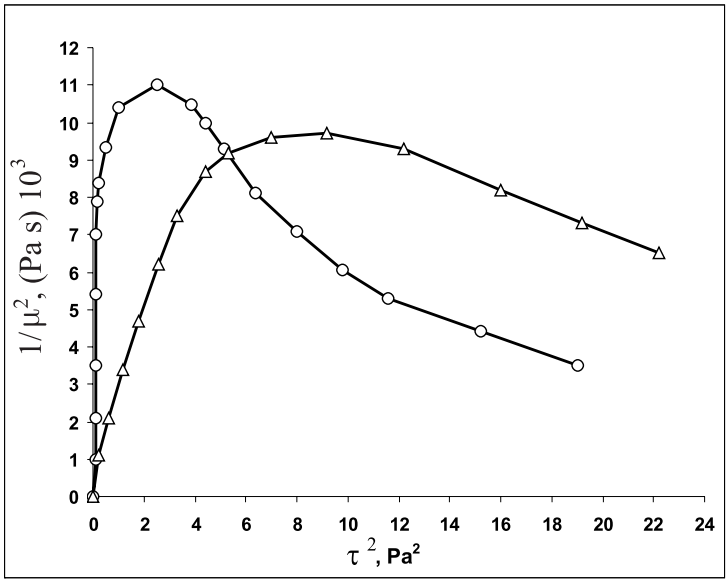

Fig. 4 Processing of results of capillary viscosimetry by Cross method

Calculations on this dependence show that intensity of intake to instem zone of intake bed ($X = 10 \div 100$) at other equal conditions of viscoelastic solution with $T = 10^3$ in 3-4 is times less than of viscoelastic fluid.

Thus, it is established, that isolation of intake beds is reached as a result of channels and cracks saturation by aerated grouting mortars showing nonequilibrium properties in "oil well-layer". The attained effect is caused by mudding processes in porous mediums, expressed in blocking of microcracks and pores of collector by gas bubbles and reducing an opportunity of fluid intake at downhole operations to minimum.

References

[1]. Mirzadzhanzade A.Kh., Seid-Rza M.K., etc. *Hydraulics of clay and cement mortals.* M.: Nedra,1965, 298 p. (Russian)

[2]. Ametov I.M., Sherstnev N.M. *Application of composite systems in technological operations of wells operation.* M.: Nedra,1989, 213 p. (Russian)

[3]. Mirzadzhanzade A.H., Karaev A.K., Shirinzade S.A. *Hydraulics in drilling and cementation of oil and gas wells.* M.: Nedra,1977, 230p. (Russian)

[4]. Shakhverdiev A.H., Panakhov G.M., Abbasov E.M. *Regulation of non-stationary processes in complex disperse systems.* Neftyanoe khozaystvo, No11, 2004, pp. 59-61. (Russian)

[5]. Sitdikov G.A. *Operative research and isolation of beds of large water permeability at wells' construction.* Avtoreferat diss. na soisk.uch. step. doktora tekhn.nauk, Moscow, MINX im. I.M.Gubkin. 1976, 53p. (Russian)

[6]. Detkov V.P. *Aerated suspensions for well cementation.* M.: Nedra, 1991, 175 p. (Russian)

[7]. Methodical guide on operative control and diagnosing of complication of hole making conditions in intake beds. Ufa, 1975, 88 p. (Russian)

Geylani M.Panakhov, Gulshen R. Afaeva
Institute of Mathematics and Mechanics of NAS of Azerbaijan
9, F.Agayev str., AZ1141, Baku, Azerbaijan

Received July 27, 2006; Revised October 25, 2006.
Translated by Mammadova E.F.