RESULTS OF INVESTIGATION OF FILTRATION PROCESSES IN OIL AND WATER SATURATED RESERVOIRS UNDER STIMULATION BY ELASTIC VIBROWAVERING

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Abstract. The results of the theoretical and experimental investigations of the low frequency elastic wavering effect on the filtration processes of phase displacement, capillary impregnation, processes of decolmatation of porous medium are presented in the paper. In the process of the theoretical analysis was found the criteria for mobilization of residual small phases, which is related with energetic field parameters – wavering acceleration and displacement, percolation analysis of phase permeabilities in the vibration field was carried out. In the process of the experimental investigations were revealed characteristic properties of the elastic vibrowavering effect, which are related with the energetic parameters of waves and properties of porous medium and saturated fluids. For the first time critical values of vibrowavering acceleration and displacement were established. The received results were used for development of new technologies of oil recovery enhancement.

Most of the known results on this subject were obtained at investigations in "high energetic" – high frequency range of frequencies [1, 2], and low frequency range 1 – 300 Hz is not studied sufficiently. The unsufficiency is in noncoordination of observations and explanation of the observed effects, the lack of the mechanisms of their description, related with the energetic and frequency parameters and with particular features of the structure and the surface of the porous medium, properties of the fluids and colmatants and also by thermodynamic conditions.

The possibility to increase mobility of "jammed" oil and water phases in the elastic vibrowavering field was evaluated on the model of interphase meniscus movement in the structure of the porous medium, represented by the system of pore expansions and contractions. Proceeding from the assumption, that arose at the wave superposition additional inertial forces, which are proportional to the wavering

acceleration of the medium $\ddot{\xi}$ and the difference of the liquid phase densities $\rho_w - \rho_p$, allow to overcome energetic barriers of adhesion forces with the solid phase, the criteria of residual oil mobilization was obtained. This criteria allows to evaluate critical values of the vibrowavering acceleration and displacement depending on parameters of the porous medium structure – characteristic radius of pore channels R_* and properties of interfacial phases

$$\ddot{\xi} \geq \frac{\sigma_{pw} - 2\psi\sqrt{\sigma_{sw}\sigma_{pw}}}{R_*^2\left(\rho_w - \rho_p\right)},$$

under the condition that vibrowavering displacement $\xi \geq R_*$. Here σ_{pw}, σ_{sw} – surface tensions on the boundaries oil-water, solid body – water, correspondingly, ψ - dimensionless coefficient., which defines the work of adhesion forces and characterize properties of the interfacial phases. Relationships of vibrowavering acceleration and displacement of the medium are defined for the given value of the undulatory resistence of the medium and density of the vibrowavering stream energy and wave frequency.

Proceeding from this condition of the mobilization and possibility of capillary redistribution of phases, percolation model is formulated, which allows to describe the macroscopic effect of the elastic vibrowavering field influence on the relative permeabilities of the porous medium for oil and water phases. Relative permeabilities relationships $f_{w,p}$ for water and oil depending on water saturation W, calculated using the abovementioned model without vibrowavering stimulation (curves 1 and 2, correspondingly) and taking into account superposition of the vibrowavering field (curves 3 and 4, correspondingly), are shown on Fig. 1. At calculation the porous medium was simulated in the form of regular three-dimensional grid with the coordination number z. For definition of the effective coefficients of phase transition was used the method of a self-coordinated field, which permits qualitatively provide for the effect of phase binding rupture, causing the termination of its mass-transfer at attaining the critical saturation. Modelling functions of capillary distribution of the porous medium by radiuses were used. From the analysis of the obtained curves it is seen that the effect of the low frequency vibrowavering field should be expected in the domain of critical values of saturations. Values of critical and residual water saturations are changing especially substantially, in this case the stimulation may influence the recovery of the residual phase mobility and involving it into a filtration flow.

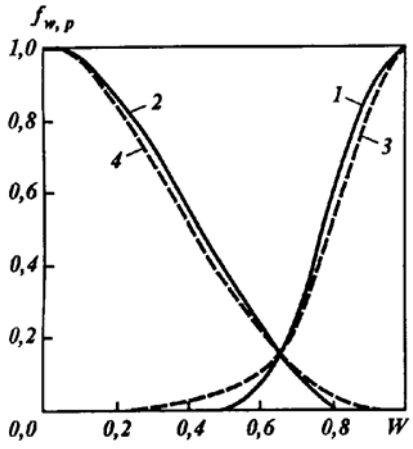

FIGURE 1. Relative permeabilities relationships $f_{w,p}$ for water and oil depending on water-saturation W.

Filtration processes in the porous

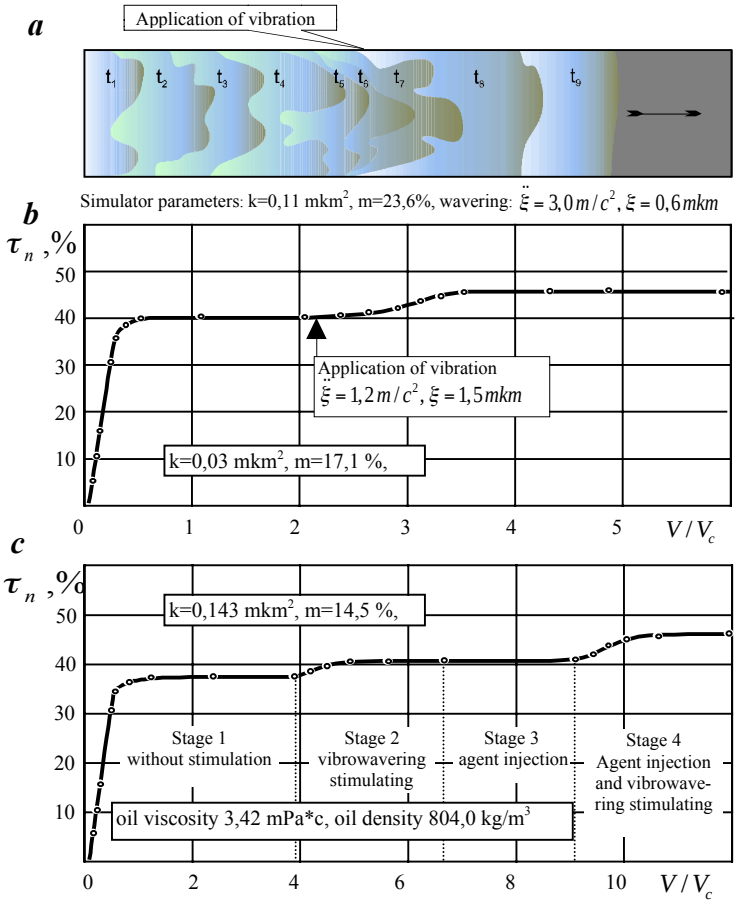

FIGURE 2. Characteristic properties of the phase displacement processes.

medium of reservoirs under the stimulation by low frequency elastic vibrowavering were investigated experimentally (Investigations were carried out together with Tufanov, I.A. and Lysenkov, A.P). Investigation were carried out using laboratory and stand field installations. These installations should have special combinatory core holder with a radiating element or a generator of elastic waves, the system providing for the constant flow rate with feeding tanks and device for measurement of the pressure drop and the flow rate drop, the system for creation of the static pressure of "press", vibration wave gauges and pressure gauges, devices for measurement of vibration wave parameters and control devices. Combinatory core holder allow to use different simulators of the porous medium of formation: porous-plate, transparent models, permitting visual observation and video recording of filtration processes, artificial volumetrical porous media and models on the base of core field samples. The frequency of elastic waves was changed in the range of 50 – 104 Hz, intensity of the vibrowavering field from 1,0 vt/m2 up to 500 vt/m2. In the process of investigation characteristic properties and energetic parameters of the elastic vibrowavering effects were determined. Satisfactory agreement with the abovementioned theoretical analysis is reached. The effect of vibrowavering in the investigated amplitude-frequency range on the process of the single-phase filtration at the absence of other residual phase traces in the medium was not found. Elastic vibrowavering has a marked effect on filtration processes at two-phase saturation. At presence of the residual phase traces in the medium dispersed drops of the residual phase are involved into the filtration flow and distinct additional recovery of the residual phase out of the porous medium is occurred. In the processes of phase displacement under the vibrowavering stimulation the replacement data are

improved significantly – the displacement front is leveled and the level of the recoverable phase displacement out of the porous medium is increased. Characteristic properties of the phase displacement processes, defined in the result of investigations are shown on Fig. 2. Thus the evolution of the displacement front of the oil simulator out of the porous-plate simulator by water is shown on Fig. 2 *a*. The curve of oil displacement by water out of the reservoir simulator made of the core package is shown on Fig. 2 *b*. An additional oil displacement from the core is resulted under the action of vibrowavering, displacement coefficient is increased. The curve of oil displacement by water, received at combination of vibrowavering and physico-chemical stimulation is shown on Fig. 2 *c*. Injection of the surfactant composition resulted in an increase of oil displacement only after stimulation by elastic vibrowavering field (stage 4). Displacement coefficient reached 46%.

CONCLUSIONS

For the first time critical values of stimulation by elastic vibtowavering on filtration processes in producing formations are determined by the parameters of vibrowavering acceleration and displacement. If express these parameters regarding the value of a free fall acceleration g and specific diameter of pore channels of the medium $\bar{d}$, then the changes of filtration processes character are observed at superposition of the vibrowavering field with parameters $\ddot{\xi} \geq (0{,}1 - 0{,}5)g$ and $\xi \geq (0{,}1 - 0{,}3)\bar{d}$. Predictions received in the result of the theoretical analysis match with the experimental results. The investigation method and determined theoretical and experimental results represent the basis for defining of optimum amplitude and frequency parameters of the elastic vibrowavering for each particular geological and field parameters and we used them for development of new technologies of oil recovery intensification under stimulation by the elastic vibrowavering [3-5], which at present are widely introduced on oil fields in Russia and were tested in other countries.

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