Linear stability of filtration of a gas and two immiscible fluids

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The linear stability of two flat at the initial moment boundaries separating, respectively, the regions of gas and water and water and oil is considered. The fluids in the system are assumed incompressible. The filtration flow is described by Darcy's law.

Using the normal mode method, relations describing the growth of perturbations of gas-water and water-oil surfaces are obtained. These relations describe the evolution of disturbances in linear approximation depending on the disturbance wavelength and main flow parameters.

The study shows that there is a threshold value of water layer thickness L_*. If the water layer thickness is greater than the threshold value, the development of disturbances at the water-gas boundary has no effect on the development of disturbances for a time comparable to the characteristic time of the oil displacement process. The expression for calculation of the threshold value is obtained

$$L > L_* = \frac{c_t - k_r + \sqrt{{c_t}^2 + {k_r}^2}}{2}, \tag{1}$$

where c_t–ratio of the considered point in time t_* to the time at which oil would have been completely displaced by water from the reservoir if both interfaces had remained flat ($0 < c_t < 1$); k_r–fluid viscosity ratio.

It follows from the results that the presence of a water layer between oil and gas significantly reduces the growth of short-wave disturbances ("fingers") in the region occupied by oil. Thus, the second fluid layer may allow to reduce the amount of residual oil, which is a big problem of effective production.