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MODELLING PROCESS OF WATER-OIL-MIXTURE DEMULSIFATION IN DEEP-WELL PUMPS

Abstract

In present paper results of theoretical and experimental researches of water-oil mix demulsifation at work of downwhole oil-field equipment (deep-well pumps) are resulted.

It is shown, that generated during movement the pump piston shock disturbance influence on intensity and demulsifation depth of water-oil mixes. Laboratory researches have shown, that the demulsifation degree depends on frequency of shock disturbance and its duration. Experiments on samples of various deposits have confirmed effect of rheophisical properties of oil (viscosity, density, content of pitches and asphaltenes) on demulsifation degree.

By exploitating oil-fields accompanied by water injection for reservoir pressure maintenance the water content in recovered production inverses. In such case mixing of oil with formation water and emulsification is unavoidable. Emulsification of oil and water at their mixing may happen both in the formation itself and in down-hole equipments (pumps, pipes and etc.). Emulsion may have very different ratio of oil and water within great percents. In majority of cases the emulsificated water is in the form of dispersed particles (emulsion type-"water in oil" w/o) [1,2].

At water inflow to the borehole in a number of cases there may be situation when produced water arranges over oil. From energetical point of view such state of the system will be unsteady. If the liquids displacement with respect to each other will happen-i.e. water will sink and low-density oil will move up, general energy of the system will decrease. Small disturbance will be sufficient to reconstruct the system and the released part of energy will be consumed for lifting of liquid.

Demulsification may happen both without application of outer influence, i.e. under the action of gravity forces, and by imposing outer vibrational disturbances [3, 4]. If the system has a steady equilibrium, the disturbances damp in due course and don't destroy the system. At unsteady equilibrium there may hold such disturbances that will increase at time and will lead to a new state of the system.

Let's study a process of emulsification of water-oil mixture without application of outer disturbances (fig.1) and under the action of vibrational disturbances

Adopt the following denotation:

M_o is oil mass in mixture, M_w is water mass in mixture, m_w is current water mass in mixture, H is the mixture height, H_h is the height of water column, $h_h(t)$ is the current height of water column, ρ_m is the density mixture, ρ_w is water density, ρ_o is oil density, V_w is water volume, V_o is oil volume, V_m is mixture volume, R is a piping radius, r is deep-well pipe radius, $\bar{h}_w(t)$ is current height of water column with regard to vibration, $h_w^g(t)$ is the current water height only with regard to gravity, $h_w^{vib}(t)$ is the current water height only with regard to vibration forces.

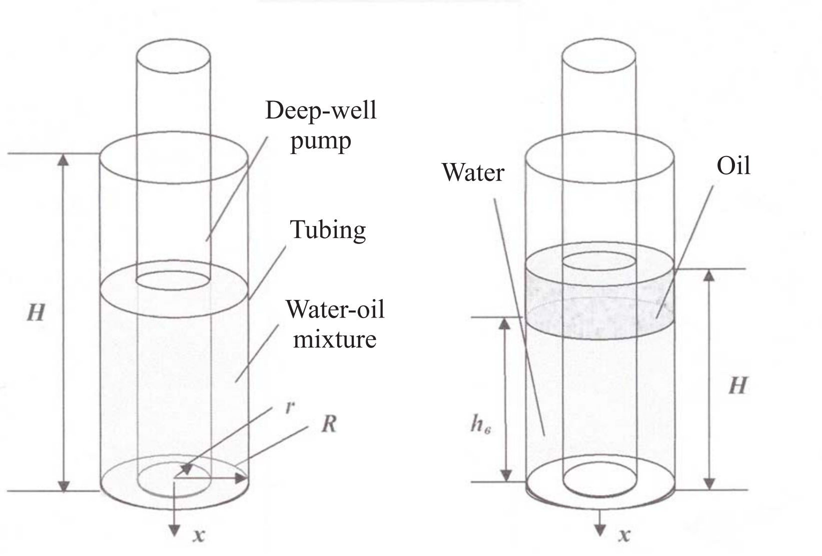

Fig.1. Initial (a) and (b) finite states of water-oil mixture at emulsification of water oil mixture without outer disturbance-under the action of gravitational forces.

Assume that the deep-well pump is in equilibrium state and water-oil demulsification in deep-well pump occurs only under the influence of gravity separation, i.e. quantity M_b is a constant quantity. Intensity of water mass separation from the mixture $m_w(t) = -\dfrac{dm_w(t)}{dt}$ in the process of mixture separation is proportional $[M_w - m_w(t)]$.

Then a differential equation of mixture destruction process without distrurbance (of the shock) will have the form

$$\frac{dm_w(t)}{dt} = k[M_w - m_w(t)], \tag{1}$$

satisfying the boundary condition:

$$m_w(t_0) = M_b, \tag{2}$$

where: k is a positive (when mixture fails) proportionality factor and is assumed to be known.

Separating the variables, we have from (1)

$$\frac{dm_w(t)}{M_w - m_w(t)} = kdt,$$

or

$$\frac{d[M_w - m_w(t)]}{M_w - m_w(t)} = kdt.$$

Finally, we get

$$m_w(t) = M_w[1 - e^{-k(t-t_0)}]. \tag{3}$$

As we see from fig.1

$$M_w = \pi\left(R^2 - r^2\right)H_w\rho_w; \qquad M_o = \pi\left(R^2 - r^2\right)H_o\rho_o;$$

$$M_m = \pi\left(R^2 - r^2\right)H\rho_m; \qquad M_m = M_w + M_o; \tag{4}$$

$$H = H_w + H_o; \qquad m_w = \pi\left(R^2 - r^2\right)\rho_w h_w(t).$$

Allowing for (4) in (3), we have:

$$\pi\left(R^2 - r^2\right)\rho_w h_w(t) = \pi\left(R^2 - r^2\right)\rho_w H_w[1 - e^{-k(t-t_0)}].$$

Consequently we have:

$$h_w(t) = H_w[1 - e^{-k(t-t_0)}]. \tag{5}$$

Obviously, proportionality factor $-k$ has different number value for different percent ratio of mixture and may be determined only by physical experiments. To determine k at constant temperature from (5) we derive the following relation:

$$k = \ln\left[1 - \frac{h_w(t)}{H_w}\right]^{-\frac{1}{t-t_0}}.$$

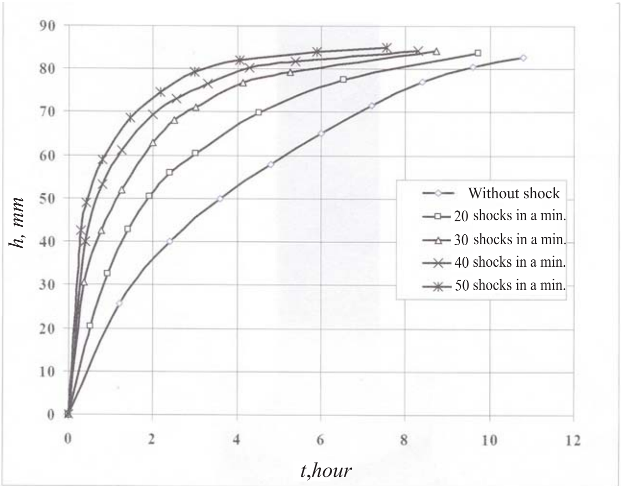

Fig.2. Theoretical dependences of change of relative height of water column in time.

In a similar way, taking into account the disturbances influence on destruction process of mixture we get:

$$h_w^{vib}(t) = \pm H_w^{vib}\left[1 - e^{-n(t-t_0)}\right],$$

where n is a proportionality coefficient taking into account the influence of disturbances (vibration) on destruction process of mixture.

Consequently, we have:

$$\bar{h}_w(t) = h_w^g(t) + h_w^{vib}(t) = H_w^g[1 - e^{-k(t-t_0)}] \pm H_w^{vib}[1 - e^{-n(t-t_0)}].$$

Whence, we have:

$$\bar{h}_w(t) = H_w^g[1 - e^{-k(t-t_0)}] \pm H_w^{vib}[1 - e^{-n(t-t_0)}].$$

Graphic description of this dependence is in fig.2.

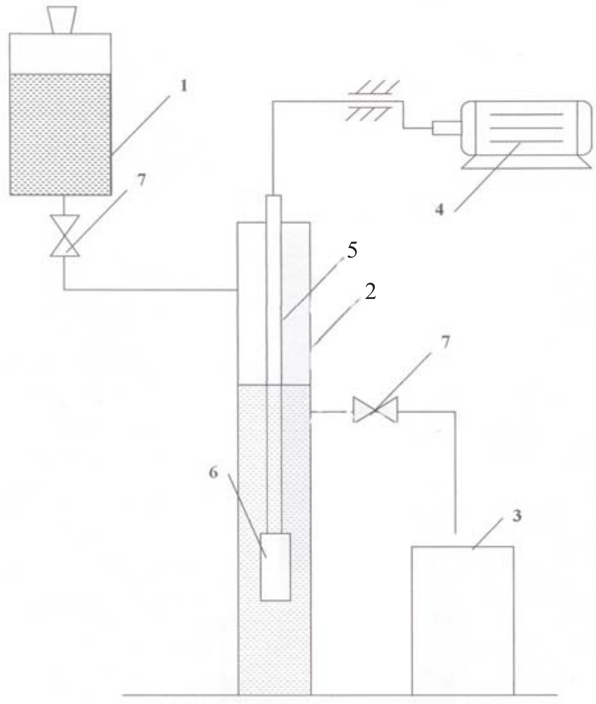

Fig.3. The scheme of experimental unit.

We have carried out laboratory experiments on influence of outer shock disturbances on water-oil emulsion simulating the regime of deep-well pumps work. Experimental installation (fig.3) consisted of the following elements: 1-capacity with liquid under investigation (water-oil emulsion); 2-piping model with sucker rods; 3-measuring capacity; 4-the engine to actuate the deep-well pumps; 5-deep-well pumps; 6-pulse generation equipment, 7-valves.

The investigations were carried out in emulsified oil selected from the wells of Azerbaijan oil fileds Binagadi, Surakhany and Muradkanly, the type of emulsion is "water in oil" at constant temperature $T = 298\ K$. The characteristics of the used samples were the followings:

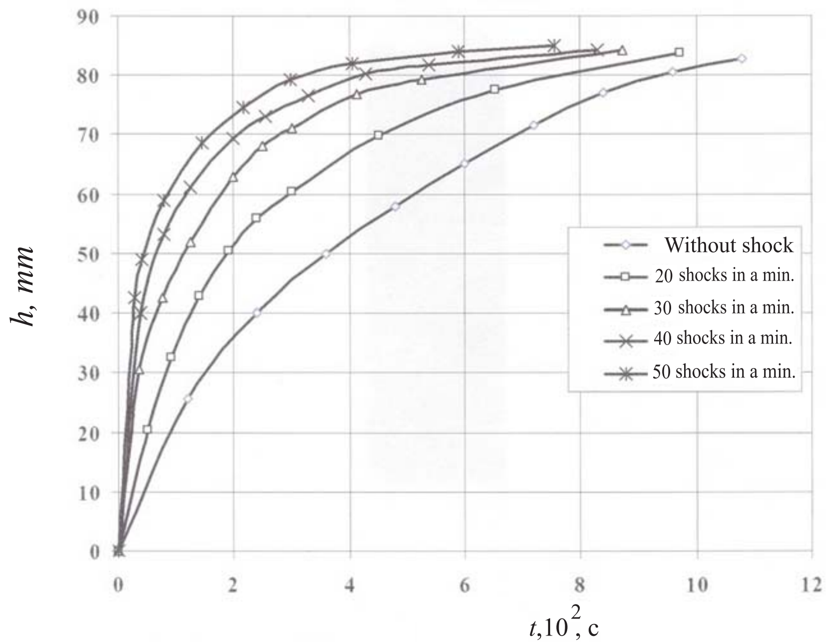

Fig.4. Change of water column height in time under the action of shock disturbances at various frequencies.

The piping model with inside placed rods and equipment to create pulses was filled with emulsified oil. The rods in the system generated disturbances following periodic shocks.

Table 1.

Oil	Density at T=298 K, kg/m^3	Kinematic viscosity at T=298K, $x10^4$, m^2/c	Asphaltenes %	Pitch, %	Paraffins, %
Surakhany oil field	883	0,155	traces	2,5	2,2
Binagadi Oil field	891	0,176	3,91	4,8	3,5
Muradkanly oil field	894	0,122	15,46	5,54	6,06

The level of water in the process of phase separation and time in the course of which the separation occurred is fixed during experiments. In fig. 4 we represent the alternation dynamics of water stratum height in the process of emulsified oil separation of Binagadi oil fields subject to the quantity of produced outer disturbances-shocks.

Graphic dependences show that both emulsion separation velocity and liquid demulsification intensity grow due to increase of quantity of shock disturbances.

In sequel, in the course of experiments we simulated the situation when we fixed the dependence of water stratum height alternation after separation on frequency of shock disturbances (member of shocks in a minute) for different effect time.

It follows from the graph that increase of outer disturbances effect leads to intensification of emulsion segregation that manifests itself in increase of height of water column in time.

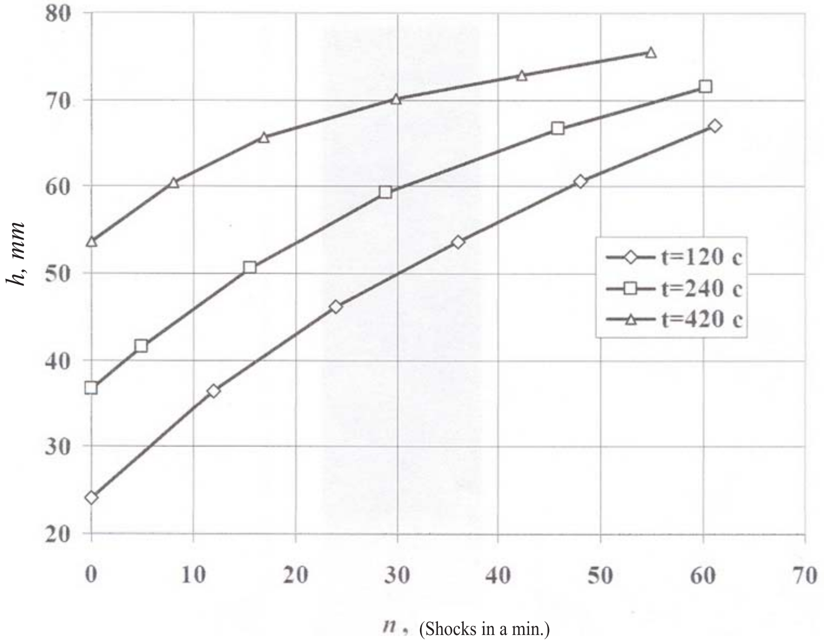

Fig.5. The dependence of water-phase height on frequency of shock disturbances is of monotone character.

In further experiments we studied the influence of shock disturbances on emulsion segregation in oil samples from different oil fields of Azerbaijan - Surakhany and Muradkhanly. The influence conditions on each of samples were identical. The alternation of height of water column was fixed both with application of disturbances and without shocks. Frequency of disturbances was 30 shocks in a minute.

As we see from fig.6 the dependences differ for each of oil samples both by separation velocity and demulsification depth. The greatest separation of emulsion is observed in Surakhany oil, and the least height of water column in oil sample of Muradkhanly deposit. In all three series we see separation stimulation by applying outer disturbances.

It seams that the distinction in separation degree for different oil samples in related with difference in their character (table 1).

Thus, the results of carried out investigations indicate interaction between shock disturbances generated during the operation of deep-well pumps and water-oil emulsion separation process in pipings. The higher is the shock frequency the more intensity of such separation, i.e. it depends on the number of rollings of pumping unit. In this case shock disturbances stimulate the demulsification process in surface separation units.

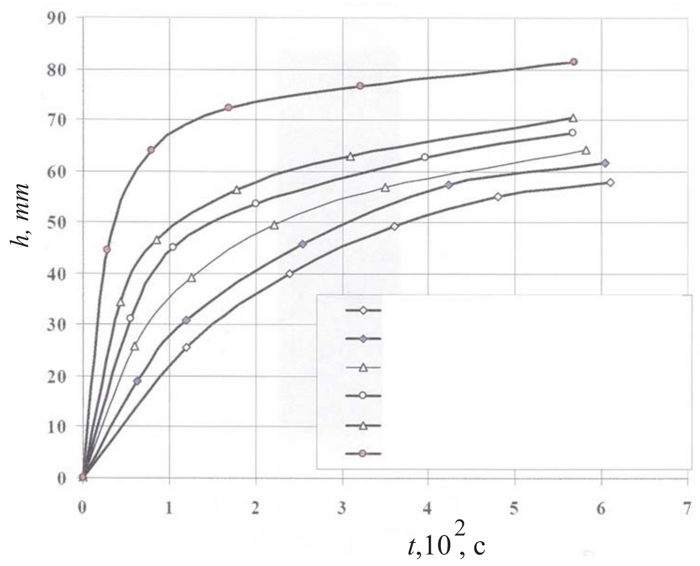

Fig. 6. Change of water column height after the effect for different oil samples.

The results of investigations may be a basis for working out practical recommendations and regulation way by demulsification process of intrawell liquid.

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