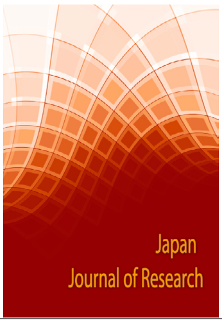
Japan Journal of Research

Short Communication



Modern Problems of Oil Production

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- Received Date: 18 Jan 2023
- Accepted Date: 28 Jan 2023
- Publication Date: 13 Feb 2023

The current stage of human development is associated with a rapid increase in energy consumption. The basis of energy production is the extraction and processing of minerals - the so-called non-renewable sources. The process of reproduction and use, disposal of waste energy sources largely depends on the cost of production. The costs of oil production, in addition to capital investments and operating costs of the field, to a large extent depend on the costs of operating an oil well with electric submersible pumps (ESP).

The centrifugal method of lifting the gas-liquid mixture from an oil well, due to the pressure-flow characteristic, is a flexible method that allows you to install various technologies.

However, the lack of a scientifically developed theory of control of electric centrifugal installations became a brake on the development of the method. This led to the fact that with the complication of the structure of the reserves of the developed fields, the technology and technical updates in the ESP continued to develop along the path of "trial and error methods", which are not very effective.

So, according to statistics, the content of the causes of ESP failures due to a decrease in the electrical resistance of the "cable line - motor" system remains constant and leads to a decrease in the overhaul period of operation.

A detailed study of the causes of ESP failures shows that the main cause of failures of electric centrifugal pumps is overheating - a change in thermodynamic operating conditions.

. 1. The solution of the problem of the thermodynamic state of a centrifugal pump when pumping out gas-liquid mixtures is given in [1,2]:

$$T_w = T_f + \frac{\phi}{1-\phi}\frac{q_o R_2 P_{sp} P_{pi}}{2(1-B)h*\Gamma*P_a}\left\{\frac{1}{\alpha}+\frac{\delta_{gt}}{\lambda_{ct}}\right\} \quad (1)$$

where: φ - content of free gas in the gas-liquid mixture at the pump intake, fractions of units; q_0- heat flux density in the pump, ; P_{sp}- saturation pressure, at.; P_{pi}- pressure at the pump intake, at.; B - water content in well production, fractions of units; h - head (pressure) created by one working apparatus of a centrifugal pump, at.; P_a -atmospheric pressure, at.; Γ - GOR, m^3/m^3; α - heat transfer coefficient, $\frac{W}{m^2*K}$; δgl - thickness of the gas layer on the heating surface of the centrifugal pump, m; χ_{ct} - coefficient of thermal conductivity of the insulating layer of gas on the surface of the centrifugal pump, $\frac{W}{m^2*K}$; R2 - outer radius of the pump, m.

When analyzing (1), the phenomenon of thermal shock was discovered [3].

The saturation pressure of oil with gas depends on temperature and is calculated by the empirical formula (2)

$$P_{sp(w)} = P_{sp(f)} + \frac{T_w - T_f}{9{,}157 + \dfrac{701.8}{\tilde{A}_{\hat{i}\grave{i}}\,(\acute{o}_{\grave{i}} - 0{,}8\,\acute{o}_{\grave{a}})}} \quad (2)$$

where; $P_{sp(w)}$- is the pressure value (at) of saturation at temperature T_w; $P_{sp(f)}$ - saturation pressure at temperature T_f ; Γ_{OM} - gas saturation (GOR), measured in , reservoir oil, characterized by the ratio of the volume (reduced to normal conditions) of gas dissolved in oil, related to the mass of degassed oil; y_m , y_a- respectively, the content of methane and nitrogen in the gas (in fractions of a unit) of a single degassing of reservoir oil under standard conditions.

Here

$$\Gamma = \rho_H \Gamma_{OM} \quad (3)$$

where: ρ_{od} - is the density of oil, under conditions at the pump intake, unit of measurement *kg/m³*.

$$C_1 = \frac{T_w - T_f}{9{,}157 + \dfrac{701.8}{\Gamma_{OM}(y_m - 0{,}8y_a)}} \quad (4)$$

$$C_2 = \frac{\phi}{1-\phi}\frac{q_0 R_2 P_{pi}}{2(1-B)hP_{at}}\left\{\frac{1}{\alpha}+\frac{\delta_{gt}}{\lambda_{ct}}\right\} \quad (5)$$

Then the temperature on the surface of the pump will be equal to:

Citation: Gareyev AA. Modern Problems of Oil production. Japan J Res. 2023;4(2):1-2.

$$T_w = T_f + \frac{C_1 P_{ps}}{1 - C_1 C_2} \qquad (6)$$

In the denominator (6), the difference is obtained and, based on physical considerations, this value cannot be equal to 0, otherwise we get an infinite increase in temperature on the pump surface, which is called "thermal shock" [4].

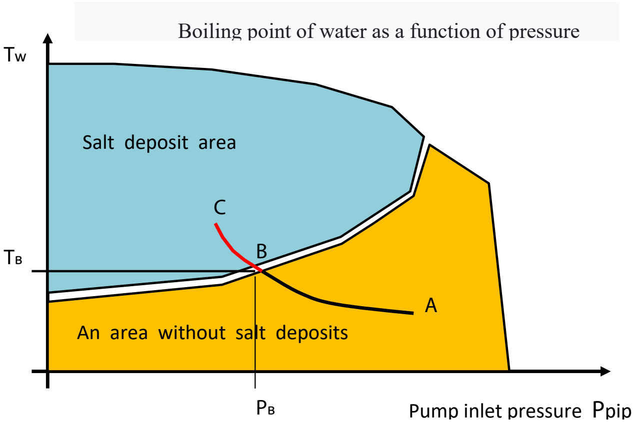

Figure 1. *Change of centrifugal pump temperature Tn as a function of pressure P_{vh} of gas-liquid mixture at the centrifugal pump inlet. P_B – boiling pressure; T_B – boiling temperature; P_{pip} – pump intel pressure; T_w – pump surface temperature.*

Based on (1), the definition of the optimal, permissible and limiting pressure at the inlet of a centrifugal pump is given [5].

Optimum pressure at the inlet to the centrifugal pump:

$$P_{pi.op.} = P_{sp}$$
$$P_{pi.pp} = P_{pi}(T_{pp}) \qquad (7)$$
$$P_{pi.u} = P_{pi}(T_u)$$

where: $P_{pi,op}$ - optimal pressure at the pump inlet; P_{sp} - saturation pressure of oil with gas; $P_{pi,pp}$ - pressure at the inlet to the pump, permissible; P_i - pressure at the pump inlet; T_{pp} - allowable temperature of the pump; T_u - limiting temperature in the pump; $P_{pi,u}$ - limiting pressure at the inlet to the pump.

4. The joint solution of equation (1) and the dependence of the boiling point of water under pressure makes it possible to control the boiling of produced water inside the centrifugal pump. By choosing the technological mode of operation of a centrifugal pump in the region below the boiling point of water, it is possible to exclude salt deposits in the cavity of a centrifugal pump [4].

Figure 1 shows graphs of the boiling point of water as a function of pressure:

$$T_w = f(P_{pi}) \qquad (8)$$

5. The pump temperature Tw can change according to curve (1). When the pump temperature changes from point A to point B, the water inside the pump is warmed; when it reaches point B with coordinates:

$$B = \mathrm{f}(P_{\mathrm{B}}; T_{\mathrm{B}}) \qquad (9)$$

inside the pump comes to a boiling point. The boiling of water occurs with the deposition of salts in the inner surface of the pump. Therefore, in order to prevent salts from depositing inside the pump, the pump temperature must be controlled so that:

$$T_w < T_B \qquad (10)$$

6. If it is impossible to operate centrifugal pump in constant mode because of small oil inflow from productive stratum, then it is necessary to transfer installation to periodic mode according to [6].

Studies of temperature operation mode of centrifugal pump according to (1) are universal, allowing to consider all aspects of installation condition. According to (1), the characteristics of productive formation, oil properties and pressure-flow characteristic of the centrifugal pump are covered in the process of operation. Calculations according to (1) do not take into account the condition of the submersible electric motor, as in the thermal process the contribution of the motor is not significant.

Implementation of the obtained results on control of electric centrifugal pump in oil production is possible only at automation of the process - based on the algorithm made on the obtained results. Automation will increase overhaul period of centrifugal pump unit operation, reduce human intervention, therefore, reduce the cost of oil production.

7. Expected economic effect from the implementation of the results obtained.

The economic effect of introducing automation of control of an electric centrifugal pump is:

1. from an increase in the overhaul period of operation of a centrifugal pump by several times;
2. a sharp decrease in the manual labor of survey operators;
3. abor of operators to bring to the technological mode of operation;
4. reducing the number of consumed centrifugal pumps;
5. reduction of downtime of wells in anticipation of repairs;
6. This excludes the use of chemical reagents and special equipment and the labor of operators, engineers to combat salt deposits.

At the same time, it is expected that the cost of oil production will decrease by up to 40%.

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