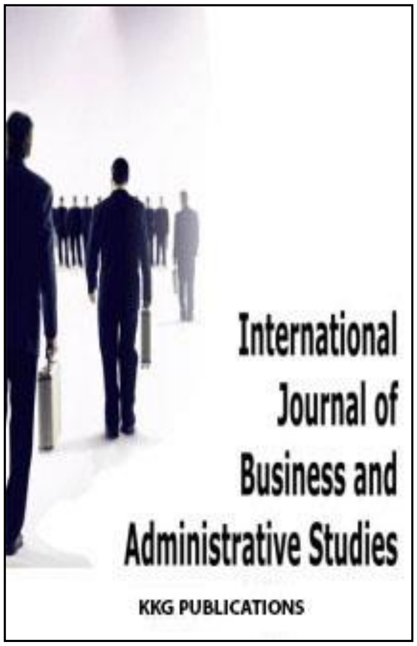

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RESEARCH ENERGY CONSUMPTION OF WELL ELECTRIC SUBMERSIBLE PUMPS FOR OIL PRODUCTION

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Abstract. Downhole artificial lift is the most energy-intensive process at the oil companies. In the current economic conditions, the oil companies are forced to optimize the power consumption for production processes. To do this, you must have a methodology for calculating the energy consumption of all oil-producing equipment. Energy losses occur in all parts of the electrical submersible pump: in the pump units: submersible motors, electrical cables, transformers and control station.. The authors conducted a study on the impact on the power consumption of various technological and operational parameters. The power loss in the electrical cable depends on its temperature. However, determining the average temperature of the cable is quite a challenge, as the temperature varies with depth of the well, there is a self-heating cable from the current flow, heat transfer through the shell with the well fluid, the fluid is heated, the heat developed operating the pump unit. The dependence of energy on the viscosity of the borehole fluid. It is known that the viscosity of the changing characteristics such as pump pressure, flow and efficiency. The use of a variable frequency drive is one of the main ways to reduce the energy intensity of the mechanized process of oil production. The paper obtained plot of the specific energy consumption of the borehole pump from frequency of the supply voltage. When adjusting the pump performance varies depression and reservoir, respectively, and the oil recovery wells. Therefore, to determine the optimal performance of the pump for the payment by a particular well is problematic. The results of these research can be useful to specialists in the development of the oil-producing enterprises of measures to optimize energy consumption.

INTRODUCTION

Difficult economic conditions, unstable oil prices and continuous growth of electricity tariffs forced oil producers to engage in optimization their costs, planning of energy consumption. It is known that the most energy-intensive technological process at the oil enterprises is a well mechanized mining (Brandt, 2011).

The Problems of Defining the Energy Efficiency of Submersible Pumps

Electric submersible pumps (ESPs) are the main way of downhole oil production in Russia. The energy of pumping unit expended to lift the wellbore fluid and the loss in all elements of the pumping unit: pump, the upstream device, the protector, the submersible motor, a cable line, a transformer, a control station and a filters (Khakimyanov & Shafikov, 2013).

Power consumption in any of the elements of ESP unit can be calculated from the known analytical expressions, but the problem of determining the specific energy consumption for each particular well is a challenge. This is due to the fact that the power consumption is affected by many technological and operational parameters, such as density, viscosity and water content of the well fluid, gas content, temperature gradient in the wellbore, and others.

For example the temperature in the wellbore affects the resistance of the cable cores to which the voltage is supplied to the submersible motor and a loss in the cable:

$$\Delta P_{\text{LINE}} = \frac{1.732 \cdot \rho \cdot L_{\text{LINE}} \cdot \left[1 + \alpha \cdot \left(T_{\text{LINE}} - 20\right)\right] \cdot I^2}{F}, \qquad (1)$$

where ρ – resistivity of the material of the cable, Ohm·m (for copper $\rho = 0{,}0195 \cdot 10^{-6}$ Ohm·m); α – coefficient of thermal expansion of copper (α=0,0041), L_{LINE} – the length of the cable line, m; T_{LINE} – average temperature of the cable line, °C; I – operating current, A; F – sectional area of the conductor, m^2.

However, determining the average temperature of the cable is quite a challenge, because the temperature varies with depth of

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the well according to the geothermal gradient, self-heating of the cable occurs current flow, heat transfer through the shell from the borehole fluid, heating liquid heat generated operating the pump unit.

The Dependence of Energy Consumption From Density and Viscosity of Wellbore Fluid

The dependence of the energy intensity of the viscosity of the wellbore fluid has a very interesting task. It is known that the viscosity of the changing characteristics such as the pump pressure, flow, pump efficiency (Vázquez, Suarez, Aponte, Ocanto & Fernandes, 2001); (Wu, Liu & Yang, 2014). These changes are defined by the appropriate factor:

$$K_{Q\nu} = 1 - 4,95 \cdot \nu^{0,85} \cdot Q_{0W}^{-0,57}, \quad (2)$$

$$K_{\eta\nu} = 1 - 1,95 \cdot \frac{\nu^{0,4}}{Q_{0W}^{0,27}}, \quad (3)$$

$$K_{H\nu} = 1 - \frac{1,07 \cdot \nu^{0,6} \cdot q_{IN}}{Q_{0W}^{0,57}}, \quad (4)$$

where $K_{Q\nu}$ – the viscosity of the flow factor; $K_{\eta\nu}$ – efficiency factor of the viscosity; $K_{H\nu}$ – pressure factor of viscosity; ν – the effective viscosity of the mixture, m^2/s; Q_{0W} – optimal flow of pump on water, m^3/day; q_{IN} – relative flow at the pump inlet.
Figure 1 shows the specific energy consumption of the ESP unit from viscosity fluid for well No 718. It can be seen that the viscosity of 0...1,4·10^{-3} m^2/s specific energy consumption will vary from 3.76 to 3.96 kW·h/m^3.

FIGURE 1
The Dependence of the Volumetric Specific Energy Consumption by ESP Unit From Wellbore Fluid Viscosity

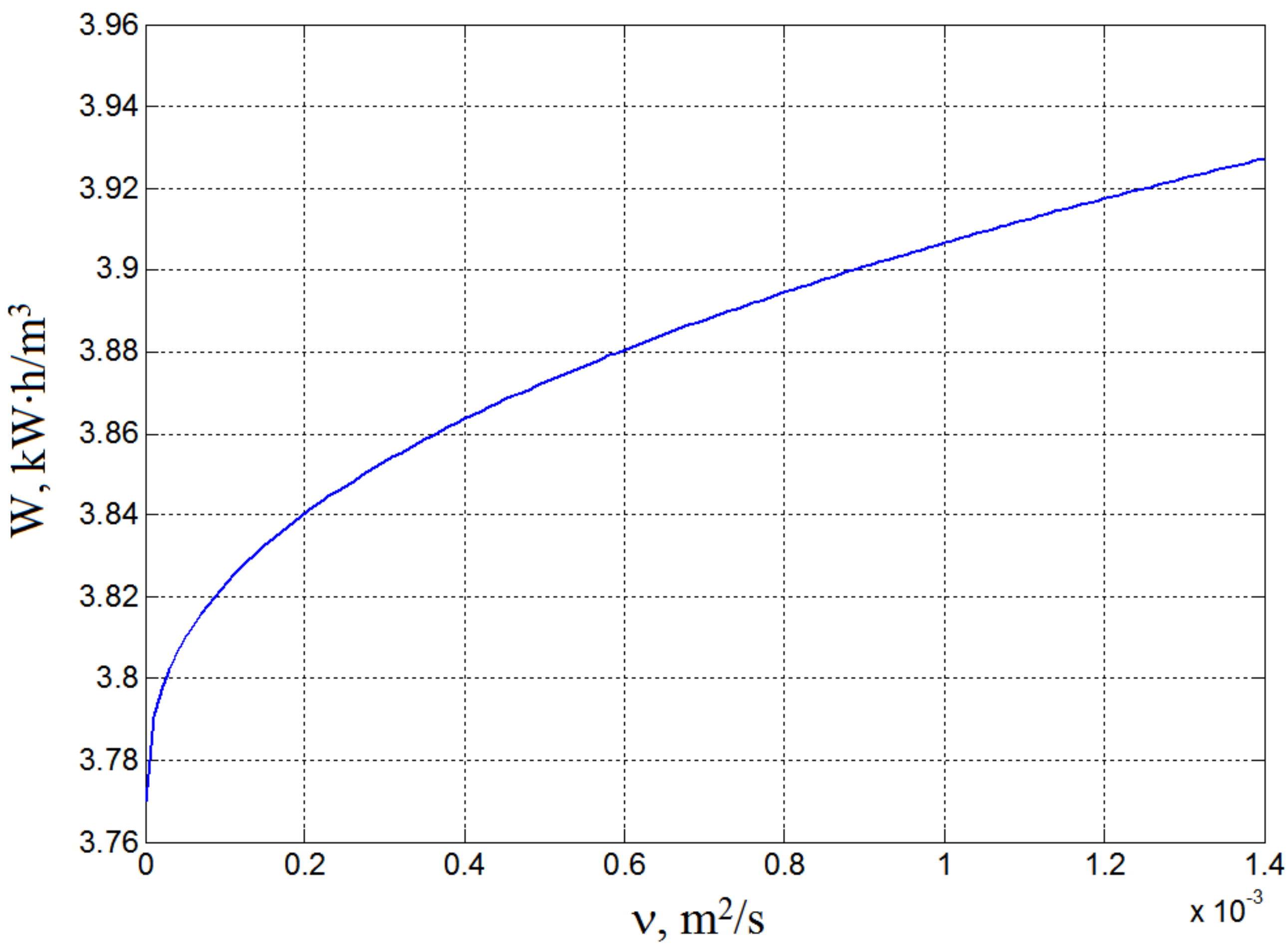


Figure 2 shows the dependence of the viscosity of the specific energy consumption at different densities of the wellbore fluid. It is seen that the viscosity increases and the energy intensity of the fluid density increases. The three-dimensional graph of dependences of energy consumption on the viscosity at different densities of the wellbore fluid is shown in Figure 3.

FIGURE 2
The Dependence of the Volumetric Specific Energy Consumption by ESP Unit Wellbore Fluid Viscosity at Different Densities.

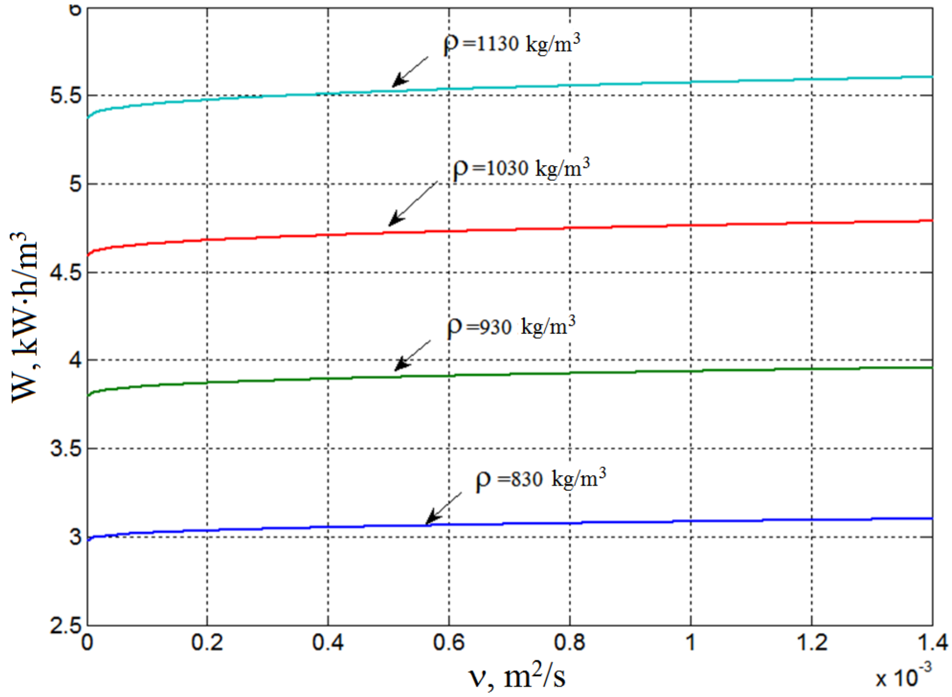
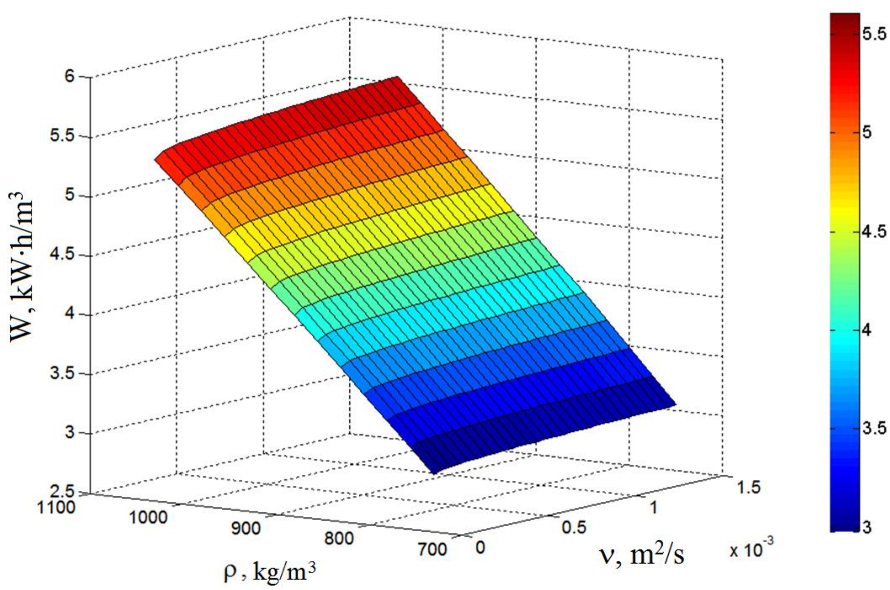


FIGURE 3
A Three-Dimensional Graph of the Power Consumption of The ESP Unit Wellbore Fluid Viscosity at Different Densities

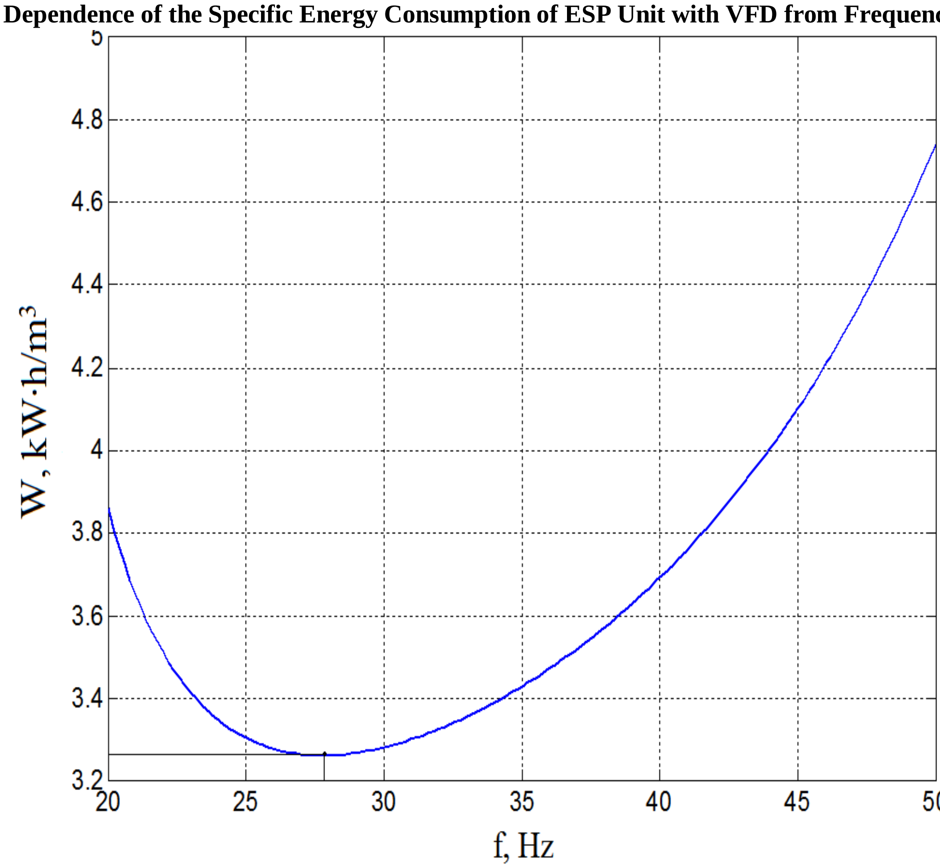


The Dependence of The Energy Consumption From The Frequency of The Supply Voltage

It is known that the use of variable frequency drive is one of the main ways to reduce the energy intensity of artificial lift processes. Today, in most cases, the optimum performance of the pump and the rotational speed of the drive motor are determined empirically - brute force with a certain step. Calculated determining optimal performance is hampered by the fact that oil recovery wells also depends on the speed of the liquid pumping. Adjusting the pump changed at depression formation, which leads to changes in inflow. Necessary data can be obtained after conducting hydrodynamic researches of wells, in particular the

measurements of the pressure build-up curve and level build-up curve (Khakimyanov, Khusainov & Shafikov, 2015).
Graph of the energy intensity of the supply voltage frequency is shown in Figure 4. The graph shows that for the minimum power consumption of the well can be achieved at a frequency of 28 Hz. At lower frequencies the power consumption is increased due to reduce the amount of recoverable liquid and at high - due to increasing power consumption motor.

FIGURE 4
Dependence of the Specific Energy Consumption of ESP Unit with VFD from Frequency



It should be noted that the mode of the well operation with the lowest specific energy consumption is not always rational from an economical point of view. When the oil is expensive and cheap electricity businesses profitably produce the maximum flow rate in any energy consumption. The cost of additional oil is higher than the total cost of electricity.

CONCLUSION

Thus, we can draw the following conclusions:

1. For an exact determination of the specific energy downhole pump units we must take into account a number of technological and operational parameters: density, viscosity and water content of the well fluid, the average temperature of the cable, the gas content and others.
2. The losses in the cable have a significant influence on power consumption of the pump unit. The losses in the cable line dependent from the temperature. Determination of the average temperature of the cable is quite a challenge. The temperature of the cable depends on the temperature gradient along the wellbore, self-heating of the cable cores of flowing current, liquid heating heat generated by operating the pump unit.
3. The density and viscosity of the wellbore fluid having a very significant impact on energy intensity. The viscosities significantly change the characteristics of the pump flow, pressure and efficiency.
4. Depression reservoir and oil recovery wells changes in the regulation of the pump. Therefore, we can not determine the optimum pump performance for a particular well by calculation. In practice, the pump capacity is determined empirically by adjusting it incrementally.
5. We can determine the relationship between depression and changes in reservoir inflows wellbore fluid according to well test, in particular by measuring of the pressure build-up curve and level build-up curve.
6. The best way to improve the efficiency of downhole pumping equipment is the use of variable frequency drive.

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