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Features of electric drive sucker rod pumps for oil production

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Features of electric drive sucker rod pumps for oil production

F A Gizatullin[1], M I Khakimyanov[2] and F F Khusainov[2]

[1] Ufa State Aviation Technical University, 12, K. Marx ave., Ufa, 450008, Russia
[2] Ufa State Petroleum Technological University, 1, Kosmonavtov ave., Ufa, 450062, Russia

E-mail: hakimyanovmi@gmail.com

Abstract. This article is about modes of operation of electric drives of downhole sucker rod pumps. Downhole oil production processes are very energy intensive. Oil fields contain many oil wells; many of them operate in inefficient modes with significant additional losses. Authors propose technical solutions to improve energy performance of a pump unit drives: counterweight balancing, reducing of electric motor power, replacing induction motors with permanent magnet motors, replacing balancer drives with chain drives, using of variable frequency drives.

1. Introduction

Production of hydrocarbons is one of the most important industries in the structure of Russia's economy. The industry provides a significant portion of foreign exchange earnings in the country's economy. It is also one of the most energy-intensive: up to 5% of all generated electricity consumed by oil-producing enterprises [1].

Downhole mechanized mining is the most energy intensive among all the technological processes of oil production. This explained by the fact that the number of wells is large; it is dispersed over large distances; many of them operate in inefficient modes with additional losses [2].

2. Sucker rod pump electrical drives

Scheme sucker rod pump (SRP) shown in figure 1. The installation consists of a control station 1, a electric motor (EM) 2, a reducing gear 3, a oscillating crank mechanism 4, a walking beam 5, a rod string 6 and a borehole pump 7.

SRP used for driving asynchronous three-phase motors EM voltage of 0.4 kV with a high starting torque. It is made with a squirrel-cage winding or the double squirrel-cage winding. The synchronous speed is 500-1500 rpm. The electric motors power is from 7.5 to 55 kW, but the most widely used EM are 22 and 30 kW [3].

SRP units have low specific power consumption values than other types of submersible pumps, but their electric drives operate in heavy modes [4]. This is due to the following factors:

- EM is selected with a power reserve. It is necessary to provide a large starting torque. After startup, it works in underload mode [5];
- The load of EM is unstable. It has a cyclic character (figure 2) [6].

The cyclic nature of the load is due to principle of operation and the kinematic scheme of SRP unit. The first half of the period is pulling out of the rod string along with the borehole fluid, the second half – down casing of rod string. At the same time, the counterweights are rising upward. When these the counterweights go upward, then the potential energy is stored, which using in the next oscillation cycle [7].

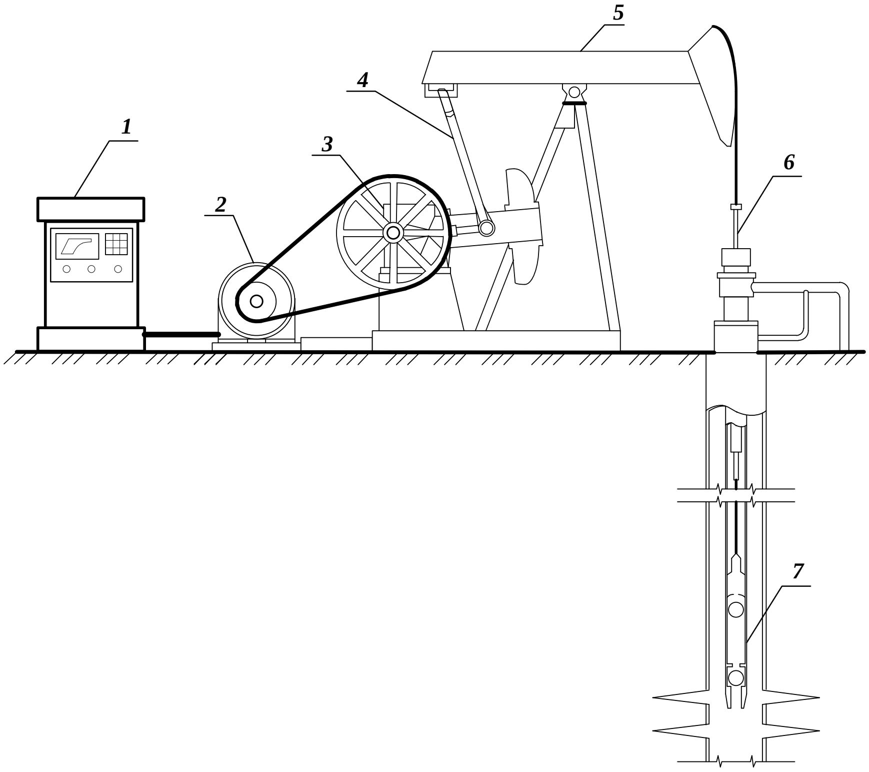

Figure 1. Scheme of sucker rod pump unit: 1 – the control station, 2 – the electric motor, 3 – the reducing gear, 4 – the oscillating crank mechanism, 5 – the walking beam, 6 – the rod string, 7 – the borehole pump.

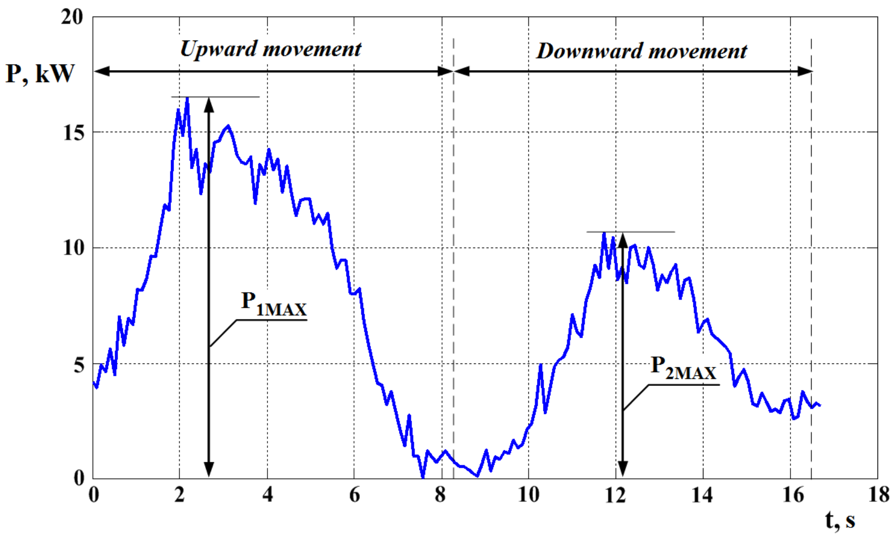

Figure 2. The load graph of SRP's electric motor per the oscillation cycle.

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The peak values of the power consumed from the network (P_{1MAX}) and (P_{2MAX}) will coincide at an ideal balancing of the installation. The load graph will not be uniform in any case. In practice, up to 90 ... 95% of units are not well balanced [8, 9].

Variability of load leads to changes in all characteristics of EM, including changes in efficiency and power factor cos φ.

3. Investigation of the variation drive parameters within the oscillation cycle

To estimate the effect of the load on the efficiency and the power factor cos φ, the typical dependences of these parameters (table 1) on capacity factor β was used:

$$\beta = \frac{P}{P_{NOM} / \eta_{NOM}}, \qquad (1)$$

where P – value of power consumption at the analyzed time; P_{NOM} – nominal capacitance of EM; η_{NOM} – nominal efficiency of EM.

Table 1. Typical depending efficiency and power factor on the capacity factor for asynchronous EM.

β	0.0	0.1	0.2	0.3	0.4	0.5	0.6
Efficiency	0.00	0.70	0.82	0.87	0.89	0.9	0.91
Power Factor	0.07	0.31	0.50	0.62	0.73	0.80	0.84
β	0.7	0.8	0.9	1.0	1.1	1.2	1.5
Efficiency	0.91	0.90	0.89	0.89	0.88	0.87	0.85
Power Factor	0.86	0.87	0.88	0.89	0.89	0.88	0.87

Calculations were performed for digitized wattmeter charts (power variation charts per oscillation cycle) of two SRP units. In both cases of EM have been installed with a rated power P_{NOM} = 30 kW.

The obtained graphs of power change, efficiency and power factor cos φ per oscillation cycle for SRP units № 1 and 2 are shown in figures 3 and 4.

As can be seen from the graphs (figure 3), the electric motor of SRP unit's № 1 is underloaded. The average power is only 6.97 kW, and the maximum - 15.56 kW. Thus the minimum power value is lowered to almost zero. Inequality peak load values at pulling out and down casing of the rod string shows the imbalance unit.

Per one oscillation cycle, the efficiency of EM varies from 0.11 to 0.90. The average value per cycle is 0.75. The power factor cos φ per oscillation cycle varies from 0.08 to 0.81. The average value per cycle is 0.49.

SRP unit № 2 is unbalanced, since the first load peak is completely absent. This is evident from the wattmeter chart of SRP unit № 2 (figure 3). The energy of EM is spent only on the lifting of counterbalancing loads, since the mass of the counterweights is too high. The rise of the borehole fluid is completely due to the potential energy accumulated in them.

The power consumption varies from 1.61 to 6.92 kW. The average power value is 3.52 kW, which indicates a low load of EM.

The electric motor efficiency varies from 0.57 to 0.83. The mean value per the oscillation cycle is 0.70. The power factor cos φ per oscillation cycle varies from 0.21 to 0.53. The mean value is 0.34.

Thus, both SRP unit are not sufficiently balanced, their EMs are underloaded. As a result, the efficiency and power factor cos φ have lower values. A significant change these parameters in each oscillation cycle adversely affects the operation of EM and electricity grid.

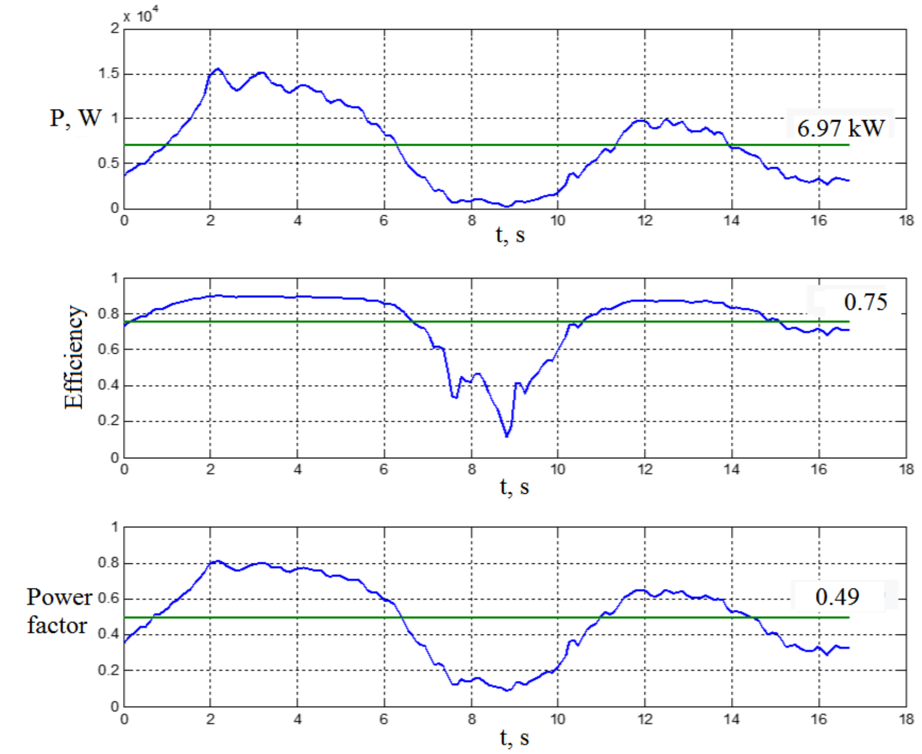

Figure 3. The graphs of power, efficiency and power factor per the oscillation cycle for SRP unit №1.

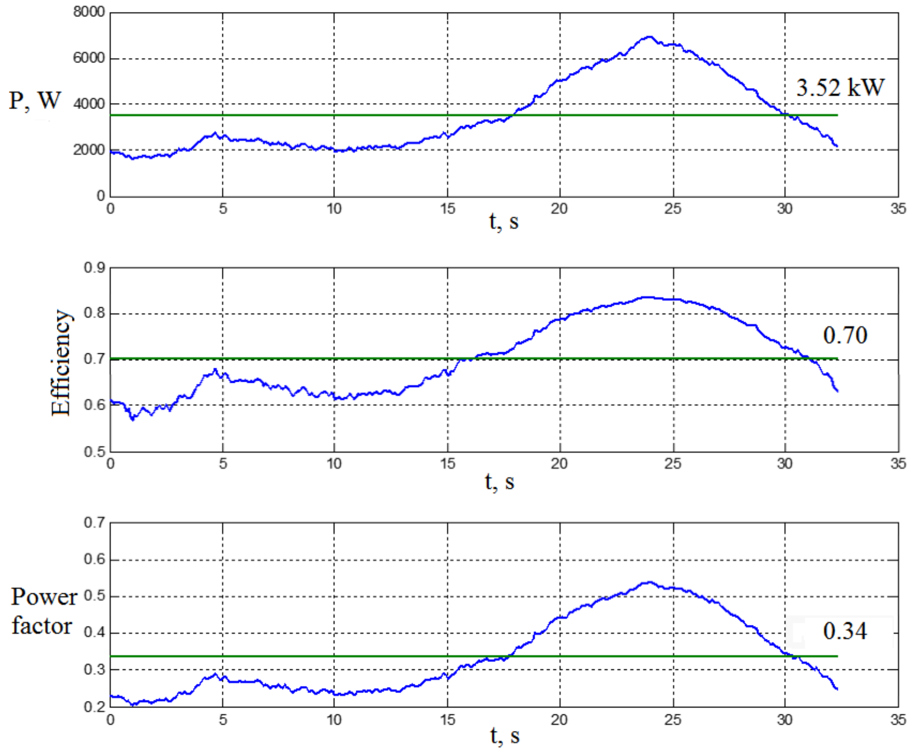

Figure 4. The graphs of power, efficiency and power factor per the oscillation cycle for SRP unit №2.

4. Recommendations for improving the operating modes of electric drives

To improve the energy characteristics of electric drives, it is required to perform their counterbalancing. Also, you need to install an EM of lower power (this requires testing according to the starting conditions, especially in winter conditions). A promising direction is to use Permanent Magnet Motors to SRP installations having high overload capacity. This will increase the loading of EM, and also achieve higher values of efficiency compared to asynchronous EM [10].

The greater stability of the parameters per the oscillation cycle is provided by SRP with chain drives. Therefore, in many fields ones are installed instead of balancing drive to improve the energy efficiency of oil processes [11].

One of the ways of increasing the efficiency of SRP is to use the variable frequency drive. This will allow you to adjust the pump performance according to recovery wellbore and to regulate the rotation speed of EM. This provides more uniform plunger movement and alignment of the load curve EM.

5. Conclusions

The conducted researches allow us to draw the following conclusions:

- The main reason for the low efficiency of SRP electric drive is the low load of motors and imbalance of counterweights.
- The inconstancy of the load per the oscillation cycle leads to changes all the characteristics of EM. This leads to a change in efficiency and power factor cos φ, which may vary within wide limits; the mean values per the cycle are very low. Changing of these parameters per the oscillation cycle negatively affects the operation of EM and the electricity grid.
- To improve the energy characteristics of electric drives SRP it is necessary to accurately balance the counterweights, as well as reduce electric power motors, allowing them to increase their load. In addition, in many cases it is advisable to replace the balancing drives with chain drives, which provide a higher stability of the parameters per the oscillation cycle.
- The promising direction is the use of valve motors for SRP drives. It has a higher efficiency than asynchronous electric motors and high overload capacity. This will increase the load of electric motors at a lower installed power.

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