Optimization Design of ESP Well Extract for Offshore Oilfield

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Abstract

As an important measure of getting stable production for ESP wells, large pump has been widely used in many fields and has an obvious effect. According to Characteristics of offshore oil well and platform, the paper optimizes the specific requirements for the optimization design of the ESP pump and the influencing factors in the designing process. Practice has proved that this technology can effectively improve the speed of production, and achieve the purpose of increasing the output of oil. It plays an important role in the stable production of oil field.

Keywords

ESP; Extraction Liquid; Optimization Design; Effect Analysis.

1. Introduction

With the development of mining, most of the offshore oil and gas fields have entered the middle and late stages of exploitation and the condition of wells are very complicated. In order to ensure that the oil fields will have stable oil production, we should pay attention to the mature oil field.

As the main way of Lifting mode in the offshore oil field, the ESP well pump change is the important measures to improve oil production. In the optimization design of ESP, we should consider all kinds of complex well conditions, including sand, wax, scaling, corrosion, well deviation, column structure, etc. We need to ensure that the ESP into the well can not only meet the reservoir requirements but also can be a reasonable operation, improve the pump inspection cycle, to achieve production and reduce the cost. Through the fine oil potential analysis, optimization design and site operation of ESP, oil extraction wells in the western South China Sea have achieved good result of increasing oil.

2. Productivity analysis of ESP well

The key of ESP optimization design is accurate to forecast an inflow characteristic (well productivity prediction and analysis) which is the extract of well pump unit selection of the first problem to be solved.

(1) The analysis and prediction of oil well productivity based on the generalized IPR curve method is a new method for predicting oil gas water three phase productivity based on the Vogel equation [1-3].

$$\frac{q}{q_{\max}} = 1 - 0.2\left(\frac{p_{wf}}{p_R}\right) - 0.8\left(\frac{p_{wf}}{p_R}\right)^2 \tag{1}$$

In this formula, $q_{\max}$ —Maximum output of pure liquid (oil) phase flow, m^3/d; J —Production fluid index, m^3/(d•MPa); p_R —Formation static pressure, MPa; p_{wf} —Bottom hole flow pressure, MPa; q —Oil well production, m^3/d.

(2) Inflow characteristics of multilayer reservoir mining. The production cost of offshore oil field is high. In order to improve the recovery rate in a short time, In order to improve the recovery rate in a short period of time, the offshore oil field often adopts multi-layer mining. The IPR curve of multilayer commingled production wells is the superposition of the IPR curve. As for the oil wells with multiple oil

layers in the same time, it is necessary to decide whether to adopt multi-layer mining or single layer mining according to the specific conditions of each reservoir.

(3) When the saturation pressure of oil wells is not clear, the proportion of water, gas and oil must be taken into account. The oil well productivity were calculated by dimensionless IPR curve and PI curve, and exploiting the historical data comparison, the weighted correction necessary

(4) In order to determine the reasonable displacement of electric submersible pump set, the trend of known oil productivity index, the actual situation of production during a certain period, and the current and future period of production capacity must be taken into consideration.

3. ESP system optimization design method and matching technology

3.1 Basic principles of optimal design

In order to ensure the efficient and reasonable operation of ESP, improve the pump inspection period, optimization design of ESP need to follow the following principles:

(1) Select the pump type reasonably, and make sure that the pump works around the maximum efficiency point of view, and consider the liquid supply capacity changes of the oil wells in 3 years;

(2) The rated displacement of pump is matched with the requirement of oil reservoir, the total pressure is equal to the rated lift well head, and meet the needs of measurement and transmission;

(3) The output power of the motor can meet the demand of lifting liquid, and can cover a wide range of stratigraphic changes as far as possible;

(4) Power cable matching specifications according to well condition and motor parameters;

(5) Selecting the size of the pipe column reasonably in order to reduce the friction loss and oil erosion, save costs, make production safely;

(6) Combining platform requirements, considering the use of electricity, and ESP to match ground equipment.

3.2 The ESP unit recommended reasonable displacement range

In order to judge whether the ESP working in high efficient area or not, the user needs to understand the characteristic curve of the pump. As can be seen from Figure 1, at the top of the parabola, the pump efficiency changes little, and the parabolic vertex is the most efficient operating point of the pump. The region which contains the point is the recommended operating area of the pump, and it is necessary to carry out a comprehensive analysis and check of the lift, displacement and shaft power in the region and its boundary.

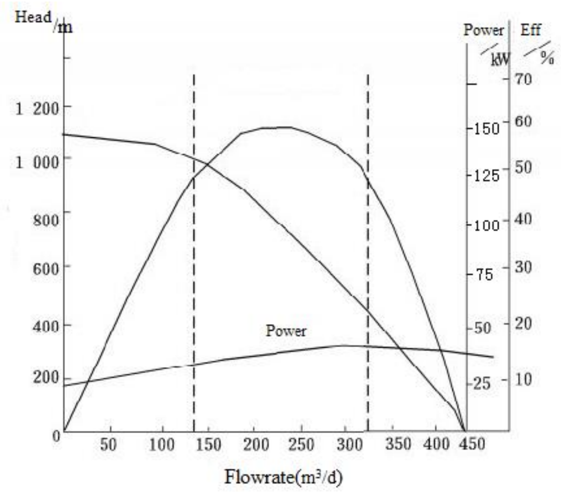

Fig.1 The characteristic curve of ESP

3.3 Pump shaft power

When the lift and model of the ESP determined, we should calculate the power of the pump shaft by using the single shaft power of the single stage pump with the maximum shaft power instead of the high efficiency point (see the formula (2)) [3].

$$P = \frac{QH\gamma_1}{8800\eta} \tag{2}$$

In this formula, P—Pump shaft power, KW; Q—Pump rated displacement, m^3/d; H—Pump head, m; γ_1—Average relative density of well fluid; η—Pump efficiency, %.

3.4 Cable selection

AWG choice depends on the length of the cable, current, resistance and voltage drop of well temperature data. The voltage drop is generally limited to 5% and the resistivity of copper is 0.017241Ω•mm^2/m. The calculation formula is as follows.

$$\rho = 0.017241 \times 1.02 \times (234.5 + T) / 254.5 \tag{3}$$

$$A = (\rho \times 1.732 \times D \times I) / \Delta V \tag{4}$$

In this formula, ρ—resistivity of conductor, Ω•mm^2/m; T—well temperature, ℃; I—Motor current, A; ΔV—Cable voltage drop, m; D—Cable length, m; A—The cross-sectional area of the cable core, mm^2.

3.5 The submergence requirements

The ESP must have sufficient submergence to normal operation. If the inlet pressure is too low, it will lead to insufficient supply or even under load shutdown, so the choice of the need to take full account of the suction flow pressure, to determine a reasonable pump hanging depth. In order to ensure the normal production of ESP, proposed design of its submergence depth is over 200 m.

3.6 The dogleg degree requirements

In the inclined or directional wells, we should consider the dogleg degree of the pump position. Under the premise of satisfying the requirement of the submergence of the centrifugal pump, the bending degree of the unit is not more than 3deg/30m in the process of the combination of different unit sizes and different casing sizes. In order to ensure the service life of ESP, ESP unit running position dogleg degree should be less than 1deg/30m.

3.7 Matching technology of high gas-oil ratio well

The pump should be deepened in the high gas-oil ratio well, so that the suction flow pressure is greater than the saturation pressure, to avoid the impact of free gas pump. If hung pump deepening cannot solve the influence of gas on the pump submersible pump system, we need to install the corresponding equipment. When the pump inlet gas volume fraction was 10% ~ 30%, we need to install the gas separator to realize the separation of oil and gas; when the pump inlet gas volume fraction was 30% ~ 70%, we can use gas processor or multiphase flow pump device to achieve gas liquid recovery.

3.8 Anti-corrosion and sand control, paraffin control, anti-scaling technology

According to the fluid composition and water content change, the degree of corrosion of the fluid is analyzed, and then the pump type and material are selected.

For sand production wells, sand washing operation should be carried out during workover operation. The amount should not exceed 500 g/m^3 sand wells; otherwise it should be put forward in the design, consultation by users and manufacturers, then according to the sand content in ESP of different grades.

For wax bearing oil wells, wax removal should be carried out in the workover operation and the corresponding measures should be taken to ensure the normal production of oil wells.

The scaling of the oil well, to use the anti-scaling electric submersible pump, also can use other anti-scaling equipment or anti-scaling measures.

3.9 The technology of condition monitoring about ESP

The conventional ESP condition tester with 6 sets of parameters: pump inlet temperature, pump inlet pressure, pump outlet pressure, motor winding temperature, leakage current and vibration. The installation of ESP working instrument can accurately predict oil production capacity, reliable and accurate real-time monitoring of the ESP and reservoir. With ESP working instrument, the engineer can understand the parameters and information of the main equipment on the ground in time, and adjust the working system of oil well in time.

3.10 Choice of tubing size

The ESP extracts well tubing size selection mainly consider 2 aspects: (1) Reduce fluid slippage loss and friction loss, give full consideration to unit energy saving; (2) To meet the requirements of reservoir single well production, and avoid the erosion of tubing.

According to the calculation formula of wellbore pipe flow, when the production of ESP well is high, the use of larger size of production pipe column can reduce the friction loss, thereby reducing the demand for the electric pump head and the motor power, saving costs.

The erosion velocity of oil pipe is directly related to the distribution of production, so it is necessary to ensure that the oil well does not run under the condition of the highest production, and the production is safe. When the erosion velocity ratio is less than 1, no erosion will occur, or erosion will occur. Therefore, the selection of tubing size to ensure the oil well production process erosion rate is less than 1.

$$V_e = K / rho^{0.5} \tag{5}$$

In this formula, V_e—Erosion velocity, *ft/s*; *rho*—Fluid mixing density, lb/ft^3; *K*—Empirical coefficient, carbon steel recommended by 100, anti-corrosion materials recommended by 200.

3.11 Ground equipment matching technology

The ESP well ground equipment mainly considers the transformer and control cabinet (inverter) selection. The capacity of the transformer should meet the requirements of the input power of the motor, and the relationship between the capacity of the transformer and the power of the motor can be expressed as follow: Transformer capacity≥Motor power/ Motor power factor.

For submersible motor, the motor power factor is generally 0.82. Taking into account the loss of the cable, the actual capacity of the transformer should also include the use of margin, therefore, the transformer capacity formula is expressed as: Transformer capacity≥(Maximum motor power/ Motor power factor+ Cable loss power) ×Safety margin coefficient.

The efficiency of the converter and the efficiency of the output filter should be considered in the selection of inverter, and its formula is as follow: Inverter power= Motor power/ (Efficiency of a booster transformer×Output filter efficiency) ×Safety margin coefficient.

According to the use of the platform and the unit, the safety factor is slightly different. In the selection of pump design, the calculation of the motor power and lift head has left a large margin, reference to general engineering, safety margin coefficient of 1.2.

4. Field test and application effect evaluation

WC-X well put into operation in May 2014, its ESP is $100m^3$/1500m, and the actual production capacity is about $180m^3/d$, which seriously deviates from the reasonable displacement of the pump unit. By the end of 2015, according to the test data, the productivity index of this well is 154 m^3/ (MPa·d), which has a great potential for fluid extraction.

In order to optimize the ESP and improve the production of oil well, in March 2016, the pump was replaced by large pump in the well, and the $400m^3$/800m ESP was chosen to enter the well. Required for the design of ESP shaft power is 60kW, the unit motor rated capacity of 87kW, to meet the needs of a certain range of frequency transfer capacity; Install electric pump instrument for real-time monitoring of the electric submersible pump and reservoir information; design of pump hanging depth is 1600m, dogleg 0.35 deg/30m (<1 deg/30m); after the operation of the pump suction pressure is 6.5 MPa; the wells of oil and gas is relatively high, the installation of gas separator; gas cable supporting 4# corrosion resistant lead sheath. Under the pump after the production of the well, the liquid production is $410m^3/d$, the oil production is $83m^3/d$, the increasing amount of oil is 55 m^3/d, and achieving an increase of oil $1.65\times10^4 m^3$ in 2016.

5. Conclusion

(1) For large pump extracts is an important measure for offshore oilfield production and stable production, is an important means of developing the old oilfield.

(2) In this paper, the author has given out the corresponding method and experience data which can be reference for oil field application engineer.

(3) In the optimization design of large pump, it should be combined with the various conditions of offshore oil well, to ensure the reasonable operation of the ESP and improve the pump inspection cycle.

Acknowledgements

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