Optimization Design of Parameters on Downhole Oil-Water Separation System of Offshore Oilfield

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Abstract

The article analyses the well selection principle and application characteristics of downhole oil-water separation. According to the characteristics of offshore oil well, the paper optimizes design of downhole oil-water separation system with dual-ESP in high water cut well, and the operating parameters are analyzed by the example design. The research results show that this technology can lead to higher economic benefit on large capacity ESP well, and provide reference for similar mining wells.

Keywords

Offshore Oilfield; Well Selection; Downhole Oil-Water Separation.

1. Introduction

After the offshore oil field enters the high water cut period, the ESP well pump change is the main measure for the stable production and the efficient development of the oil field. Large displacement ESP consumes a lot of power, increase power and more control equipment, while a large number of output water on the platform of the water treatment capacity, sea amount of liquid transport capacity is a huge challenge.

Downhole oil-water separation is installed in the downhole, most water separated from the booster in produced fluid in the wellbore after injected directly into the stratum, and the fluid rich in oil lifting to the ground[1-2]. The successful application of this technique can effectively reduce sewage lifting, greatly reducing the burden of platform of water treatment system, the release of sea pipe space, to reduce platform transformation and reduce the energy consumption and cost, reduce the environmental pressure and improve the production rate and recovery rate has important significance.

2. Structure and working principle of downhole oil and water separation system

2.1 Structure of downhole oil and water separation system

ESP downhole oil-water separation system including single pump single motor and double pump single motor, dual pump motor 3 structure. For the offshore oil wells, the dual pump and double motor downhole oil water separation structure is more adaptable and reliable.

Dual ESP downhole oil-water separation system consists of 5 subsystems, including production layer, injection layer, wellbore flow, dual ESP and water separator[3-4]. Dual ESP system and downhole oil-water separator system is the most important part. Dual ESP subsystem consists of dual ESP, cable and ground control part. The lower unit provides lifting and injection of energy, and the upper unit provides lifting energy. Downhole oil-water separator is the core of the coordination work of the whole system.

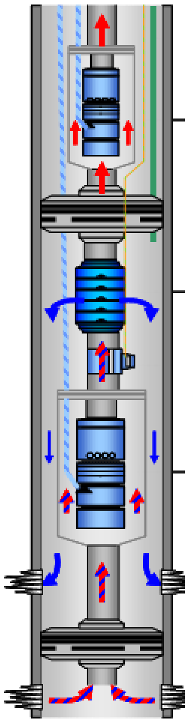


Fig.1 Structure indication of downhole oil-water separation system with double ESP

2.2 Working principle of downhole oil and water separation system

Dual ESP downhole oil-water separation system structure and work flow as shown in fig.1.

3. Optimization design of oil and water separation system in offshore oil field

3.1 Principle of well selection

For offshore oil fields, the application of downhole oil and water separation technology needs the following conditions:

(1) The water injection layer has better injection capacity, and the water injection layer is not connected with the production layer.

(2) The compatibility of the output water and the water injection layer is good, and the incompatibility of the fluid properties will lead to the blockage of the injection layer and the decrease of the injection capacity.

(3) 9-5/8 production casing is best to ensure greater economy.

(4) The structure of the well is reasonable, and the best section of the equipment is the vertical section to maintain good production effect.

(5) For the density difference between oil and water is more than 10%, the moisture content is more than 85%, in order to achieve better effect of oil-water separation.

(6) The well condition is required to be clean, without sand, fouling, wax and so on.

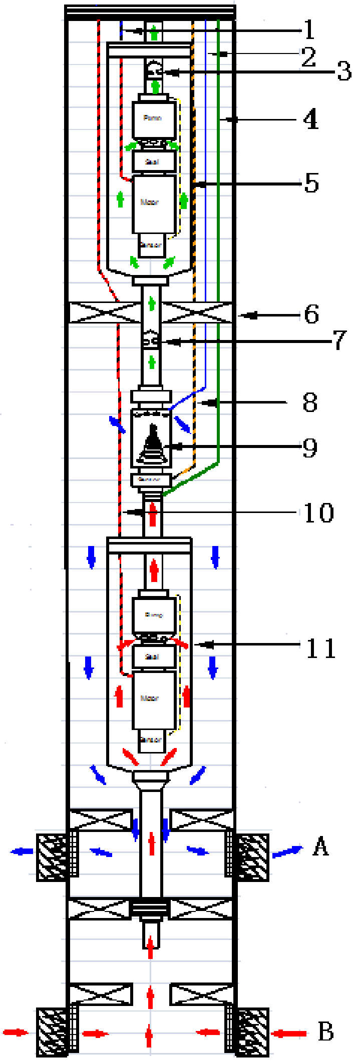
(7) The platform has a workover machine to reduce the cost of action.

(8) Accurate and reliable water injection and production reservoir data are the key to the success of the technology.

3.2 Optimization of system structure scheme

The design of downhole oil and water separation system needs to meet two requirements of lifting and injection at the same time. According to the well fluid supply capacity determination of oil well liquid production target, the relevant parameters of double electric submersible pump unit and oil-water separator, the dual electric submersible pump units to achieve the highest efficiency and minimum energy consumption.

While selecting the equipment of downhole oil and water separation system, combined with the production characteristics of offshore oil well, the pipe string structure is optimized and adjusted. As shown in Fig.2, the whole system has the following functions.



1.Upper ESP Power Cable
2.Injection Water Sampling Line
3.ADV valve
4.Chemical Injection Line
5.Upper Canned ESP
6.Packer
7.ADV valve
8.Sensing signal transmission line
9.Oil-water Separator
10.Lower ESP Power Cable
11.Lower Canned ESP
A.Injection layer
B.Production layer

Fig. 2 Optimization of pipe column structure of oil and water separation system in offshore oil field

(1) Dual frequency conversion control dual electric submersible pump. The frequency converter is widely used in the offshore oil field. Through the frequency conversion technology, the production parameters of the double electric pump are adjusted, the oil production capacity and the lifting and supercharging capacity of the electric pump unit are adjusted. The injection pressure is adjusted in time according to the change of injection capacity of the water injection layer.

(2) Real time monitoring of pressure monitoring system. The pressure monitoring system is installed in both the double electric pump and the oil-water separator, which can monitor the change of the pressure of the production layer and the water injection ability of the injection layer in real time.

(3) Injection water sampling function. The injection water sampling pipeline is added, and the injection water sample can be obtained in time. According to the measured oil and suspended solids content of electric submersible pump variable frequency regulating speed up the separation, to improve the separation effect but also can adjust the chemical formula and injection quantity.

(4) Chemical injection function. The liquid control pipeline is connected to the inlet of the oil-water separator, and the injection of chemicals is adjusted according to the change of injected water quality,

so that the oil-water separator achieves the best separation effect and improves the quality of injected water.

(5) Acidification function of water injection layer. There are two ADV valves in the design of the pipe string. If the injection pressure increases or fails to enter, the injection of chemical agent can be realized through the automatic reversing valve, and the acidizing operation of the water injection layer is carried out.

4. Analysis of calculation examples and parameters matching

4.1 An example

A well is 9-5/8" casing, with good water injection level, oil and water density difference 16.67%, water content 86.5%, no sand, and the well production of a large amount of liquid. The design of oil and water separation for the well can release the space of the liquid quantity of the platform to the maximum. The detailed data is shown in Table 1.

Table 1 The basic data

Production layer（m）	Static pressure of production layer（MPa）	productivity index（m^3/d/MPa）	Saturation pressure（MPa）	Injection layer（m）	Static pressure of injection layer（MPa）	Injectivity index（m^3/d/MPa）
1 496.3～1 560.7	11.9	1 120	3.5	1 137～1 348.2	11.78	1 000

The downhole oil-water separation plan is designed for the well. The target production volume is 3000 m3/d, the wellhead oil pressure is 1.5 MPa, the wellhead water content is 50%, and the inlet pressure of the pump is greater than the saturation pressure. The design results are shown in Table 2. At the same time, the auxiliary double stage spiral oil water separator is selected, the outer diameter is 7 ", it is produced by 4-1/2" 12.6ppf tubing, and the structure design of the pipe column is shown in Fig.2.

Table 2. Dual ESP downhole oil-water separation system design results

Liquid production(m^3/d)	3000
Oil production(m^3/d)	418
Bottom hole flow pressure(MPa)	9.57
Water injection rate(m^3/d)	2150
Lower pump setting depth(m)	1063
Lower pump series /Lower pump type	60 /P200
Lower pump motor power(kW)/ load	494 / 77.02%
injection pressure(MPa)	14.63
Wellhead oil pressure(MPa)	1.95
Upper pump setting depth（m）	998
Upper pump series / Upper pump type	72 /P60
Upper pump motor power(kW)/ load	74/ 82.07%

4.2 Parameter matching analysis

The sensitivity analysis of underground oil-water separation system mainly includes injection and output parameters[6-7], but there is less content with the combination of offshore platform's space, equipment, energy consumption and later operation. Aiming at the actual example well, parameter matching analysis is made from various aspects, such as the key factors that affect the selection of system equipment, the platform space and the power consumption, and the plugging of injection capacity after production.

4.2.1 Analysis of liquid production and Injectivity index

The capacity of liquid production and water injection is the key factor in the design of the downhole oil and water separation system, which directly affects the equipment selection of the system.

(1) The effect of target liquid production. The target liquid production is the output of the lower pump, the impact on the design of the system as shown in Fig.3. The greater the output of the lower pump, the greater the fluid volume of the lifting and injection of the system, the higher the required injection pressure, the inlet pressure of the separator and the outlet pressure of the separator. The entrance pressure of upper pump is affected by the two aspects, the separator outlet pressure and the pressure for lifting liquid, for the example well, the liquid content of oil rich after separation increases with the increase of total liquid production, the pressure change of lifting is greater than that of the outlet pressure of the separator, therefore the upper pump entrance pressure decreases, which is required for the upper pump head increased.

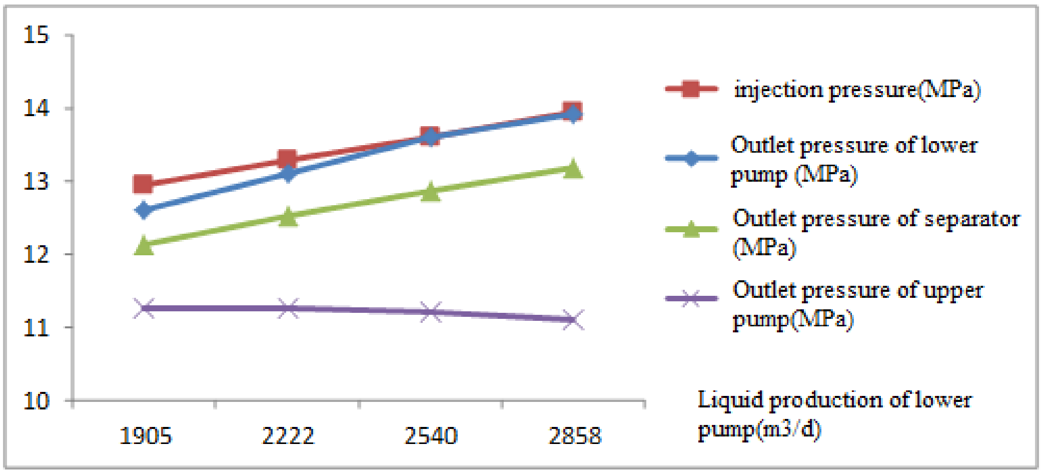


Fig.3 The relationship between the amount of liquid production and various pressures

(2) The influence of water injection index. Water injection index determines the injection capacity. The relationship between water injection index and pressure is shown in Fig.4. The higher the water injection index, the smaller the injection pressure needed, the lower the lift required for the pump. At the same time, the entrance pressure of pump is reduced, in order to meet the demand of the oil rich fluid lift pump, required lift increase.

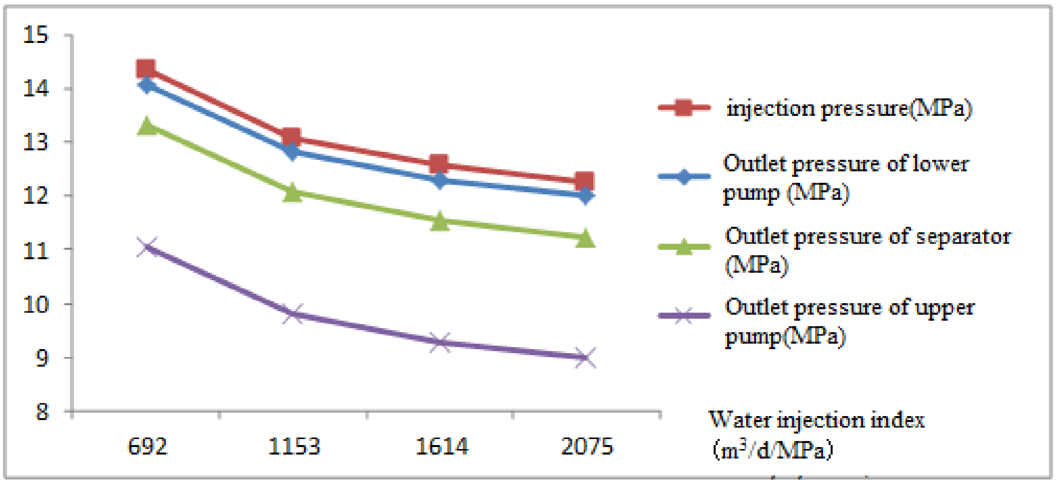


Fig.4 The relationship between water injection index and various pressures

4.2.2 Analysis of motor power and energy consumption

The design requirement of offshore oil-water separation system is to make the whole system achieve the highest efficiency and the lowest energy consumption, while reducing the platform volume and processing space without increasing the power consumption of the platform.

Table 3 shows the configuration and power consumption of ESP in the lower frequency under different operation. When 60Hz runs, the electric pump series needs 60 stages, the motor power is 494kW, the frequency converter is 748KVA, the power demand is minimum, and the frequency converter is suitable for the existing platform space. The actual operating frequency of the lower ESP under specific conditions is only 55.5Hz, and it has the proper adjustment space, which is more flexible, as shown in Figure 5. Therefore, the design scheme based on 60Hz is the best choice.

Table 3.Comparison of energy consumption under different frequency design

The ESP frequency（Hz）	ESP		Pump motor power(kW)	Frequency converter power（KVA）
	Pump type	Pump series		
50	562 P200	145	956	1227
55	562 P200	73	595	792
60	562 P200	60	494	748

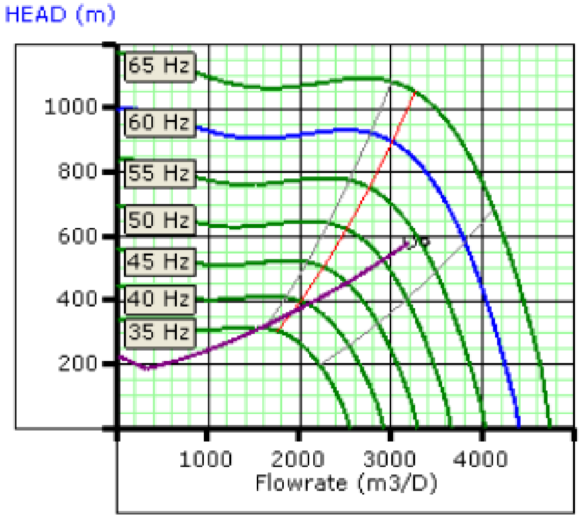


Fig.5 Operating conditions of a lower pump unit at 60Hz

4.2.3 Analysis on the injection capacity of acidification agent

The structure of the pipe column is optimized so that it has the acidification function of the water injection layer. The pipe column is designed with two ADV valves, as shown in Figure 2. The acidizing agent is injected from the wellhead. After the first ADV, it reaches second ADV through the annulus of the upper canned ESP, and comes out by second ADV. The water injection layer is injected through the lower production string and the 9-5/8 casing annulus, so as to achieve the acidizing purpose.

The flow path of acidifying agents can be divided into three segments. L1 is the upper 4-1/2 "12.6ppf tubing, inner diameter 3.958", with a length of about 990 m. L2 is the annulus in the upper canned unit, its overflow area is equivalent to 2.916 ", the length is about 25 m. The L3 section is the distance between the packer and the injection layer, and the equivalent inner diameter of the overflow area is 6.616 "and the length is about 210 m.

(1) The relationship between injection and friction. The friction analysis of acidification agents through different paths is shown in Fig.6. The friction resistance is greatly influenced by the injection amount, and the friction resistance increases significantly when the injection amount is increased. The L2 and L3 segments have little influence on the friction, because the L2 segment has a short overflow area, but its path is short, while the L3 section has a long path, but its overflow area is large.

(2) The relationship between injection flow and injection pressure. The relationship between injection flow and injection pressure is shown in Fig.7. The injection pressure of the underground and the ground increases with the increase of the injection amount.

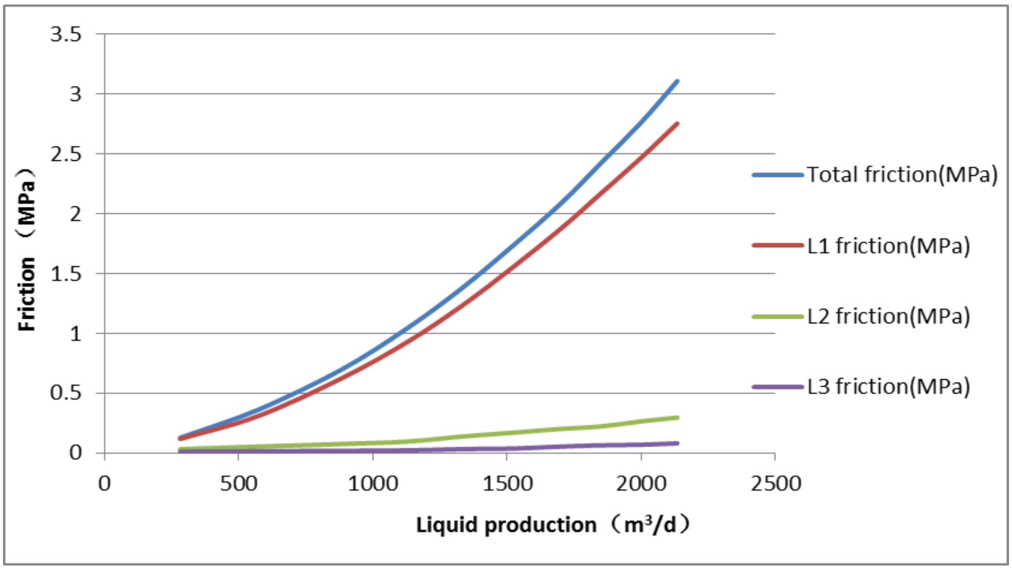


Fig.6 The relationship between injection flow and friction

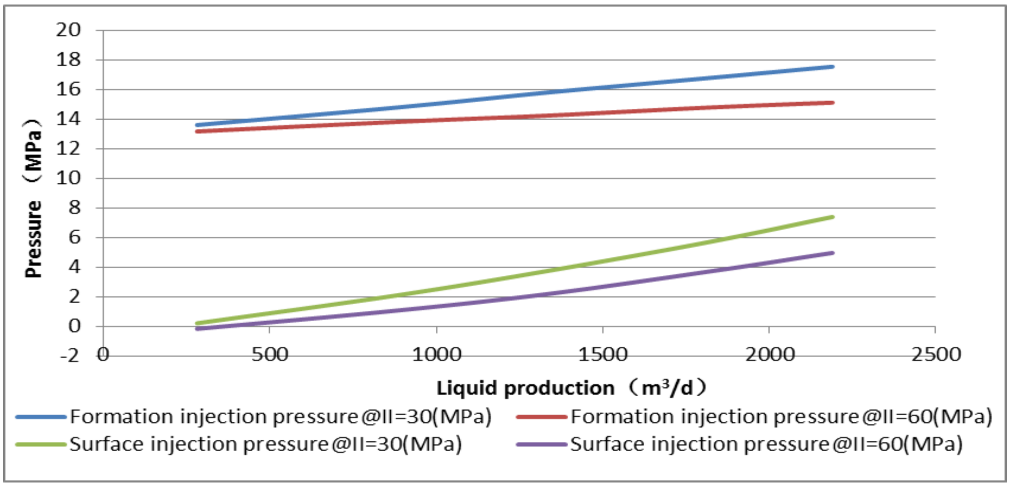


Fig.7 The relationship between injection flow and injection pressure

5. Conclusion

(1) In this paper, the well selection principle and favorable conditions for oil and water separation technology in offshore oil field are summarized. Combined with the characteristics of offshore oil well optimized dual ESP downhole oil-water separation system, it can realize the system control of ground, underground monitoring and injected water quality monitoring, injection parameter adjustment, chemical injection, water injection layer acidification function.

(2) The quantity of target liquid production and water injection index are the key factors affecting the selection of equipment. Increasing the operating frequency of the ESP can greatly reduce the energy consumption of the system, and the acidification of the injection layer is convenient and easy.

(3) The design example shows that the technology can effectively solve the bottleneck problem of water treatment and liquid extraction in offshore oil field.

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