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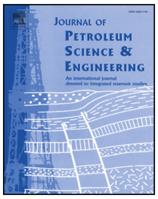

Study on energy conservation water injection system of offshore platform based on jet pump

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ABSTRACT

In order to reduce energy consumption of water injection development of offshore platform, one idea of jet pumps with characteristics of suction replace the gate valve of water injection wells was introduced. Taking 14 injection wells at a platform in Bohai as the study object, three types of jet pumps which are called JP1, JP2 and JP3 were designed. The corresponding three-dimensional models were established and the Realizable k-ε model of ANSYS was applied to study the influence of jet pump nozzle-throat clearance on water injection rate. Moreover, the injection performance of structure-optimized jet pumps was tested. Three conclusions could be drawn. First, JP1, JP2 and JP3 express the best water injection performance with the optimal nozzle-to-throat clearance which is 4 mm, 5 mm and 6 mm. Second, the water injection rate could satisfy the demand of water injection platform and simulation results are similar to the experimental ones when the water injection rate range of three kinds of jet pump is 183–272 m^3/d, 263–393 m^3/d and 634–1149 m^3/d respectively. Third, compared with the throttle valve water injection system at offshore platform, the jet pump water injection system could save about 1,150,000 kW h per year.

1. Introduction

Intensification is the common method which is applied in water injection at offshore oilfield. In other words, the water injection pump system with the corresponding type and pressure level on the platform is configured so that high pressure water that is pressurized by water injection pump can flow through a set of water filling tubes and is distributed to the wellhead (Fan et al., 2011b). Due to heterogeneity of layers of different water injection wells and the other reasons, the injected pressure of each well is different. When the requirement of the injected pressure of the highest pressurized well is satisfied, the other low pressurized wells need to be throttled and depressurized by valves. As expressed in documentation, energy consumption caused by water injection system accounted for 30%–40% of total energy consumption at offshore oilfield (Guan et al., 2014). Various articles which aim at reducing energy consumption of water injection system have found some solutions (Chaban et al., 2011; Wang Yunxian et al., 2012; Zhao et al., 2006; Cheng et al., 2012), such as optimized systems, pulse water injection and partial pressure water injection. Therefore, it is proposed to replace the throttle valve device with the jet pump to reduce energy consumption in this article. Jet pump can transform the pressure energy of high pressure fluid into dynamic energy, convert high-pressure fluid into high-velocity fluid, and use dynamic energy to pump the low-pressure water stored on the platform. It will meet the pressure and flowrate demands of water injection well, and also reduce the supply of high pressure water on the platform. Take the water injection system of one platform of the Bohai Sea as an example, the structure of the jet pump will be obtained by theoretical design and Fluent numerical simulation. At last, the water injection performance is verified by an experiment.

2. Parameters and analysis of one platform of the Bohai Sea

Based on the field data of an oil production platform in Bohai, China, Table 1 lists the specific data of injection pressure and flowrate for each injection well of this platform (2013–2014). The highest injected pressure of this platform is 13 MPa and pressure of $12^{\#}$-$14^{\#}$ wells are around this highest value. In this situation, the energy-saving effect of the jet pump is not obvious. Jet pumps can be installed on the other 11 water injection wells so that pressure can be adjusted. The injected pressure of $1^{\#}$ and $2^{\#}$ is between 4 MPa and 7 MPa, the injected flow is between 250 m^3/d and 150 m^3/d. The injected pressure of $3^{\#}$ to $5^{\#}$ is between 4 MPa and 7 MPa, the injected flow is between 350 m^3/d and 250 m^3/d. The injected pressure of $6^{\#}$ to $11^{\#}$ is between 4 MPa and

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Table 1
Parameters of water injection wells of platformsin Bohai.

Injection well number	Injection pressure/ (MPa)	Injection flow/ (m^3/d)
$1^{\#}\sim2^{\#}$	4–7	250–150
$3^{\#}\sim5^{\#}$	4–7	350–250
$6^{\#}\sim11^{\#}$	4–8	1000–600
$12^{\#}\sim14^{\#}$	11–13	–

8 MPa, the injected flow is between 1000 m^3/d and 600 m^3/d. 1 MPa low pressure water of this platform is employed as supplemental water of jet pump's suction side.

3. The initial design of the structure of the jet pump

Jet pump is mainly composed of nozzle, throat, diffusion tube and suction chamber, as shown in Fig. 1. It can be seen that after the high-pressure fluid passes through the nozzle, the pressure energy is converted into dynamic energy and the velocity is significantly increased. In fact, the low pressure fluid flow into the jet pump carried by the high velocity fluid and the effect of the pressure difference. Then, the two fluids are mixed intensively in the suction chamber and the throat, finally the pressure is increased while velocity is reducted at the diffusive tube.

According to the design method of the jet pump of Lu Hongqi and Brown K E (Brown, 1987; Hongqi, 2004), the flowchart of the design jet pump was arranged and planned, as shown in Fig. 2. P_n, P_s, and P_d stand for pressure of high pressure fluid, pressure of low pressure fluid and the outlet pressure of jet pump. Q_n, Q_d and Q_l stand for the high pressure fluid flowrate, the outlet fluid flowrate and the low pressure fluid flowrate respectively. d, D, L_c, L_k and D_0 can refer to Fig. 1.

The meaning of dimensionless parameters R, M and N are shown below.

1) Area ratio

$$R = \frac{A_n}{A_t}$$

A_n and A_t stand for the area of nozzle and throat respectively.

2) Flow ratio

$$M = \frac{Q_l}{Q_n}$$

3) Pressure ratio

$$N = \frac{P_d - P_s}{P_n - P_d}$$

4) Efficiency

$$\eta = MN$$

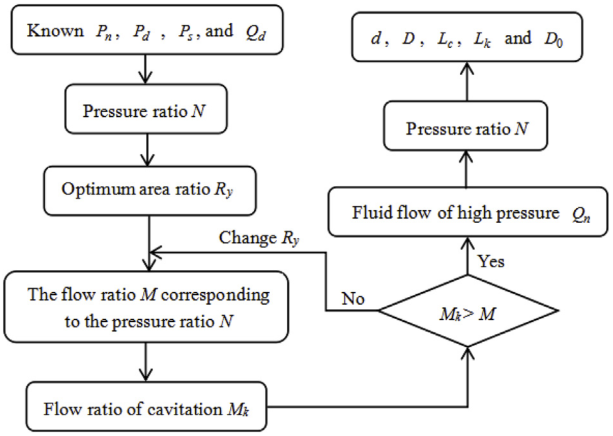

Fig. 2. Jet pump design flowchart.

Table 2
Main parameters of jet pump size.

Type	Nozzle Diameter d /(mm)	Throat Diameter D /(mm)	Throat Length L_k/(mm)	Nozzle-to-Throat L_c /(mm)	Diffusion Tube Diameter D_0 (mm)
JP1	3.8	5.6	113	2.8–5.6	23
JP2	4.4	6.1	113	3.3–6.6	23
JP3	7.4	10.9	113	5.5–12	23

In order to improve performance of the jet pump and reduce the flow losses, a streamlined nozzle is selected (Xiong et al., 2009). According to the rules of structural design and characteristics of jet pump, three types of jet pumps can be employed to satisfy requirement of each water injection well. The parameters of jet pump size are shown in Table 2 and the structure chart is shown in Fig. 1.

4. Numerical simulation and structure optimization of flow field of jet pump

At present, the design and calculation method of jet pump can only give a range for specific structural parameters (like L_c). However, numerical simulation (Fan et al., 2011a; Wang et al., 2006) can help to obtain the optimal parameter instead of a range. L_c (nozzle-to-throat clearance) is the key factor that affects the performance of the jet pump. Since nozzle-to-throat clearance in Table 2 is still uncertain, the first step is to ensure the optimal nozzle-to-throat clearance of each pump that obtained by numerical simulation.

4.1. Model and related settings

First of all, a 3D model was built according to the designed size of the jet pump. For this modeling, the effect of the suction chamber's position to the inner flow field was neglected (Zhu et al., 2012) and geometric construction is simplified. The simulated model is expressed in Fig. 3.

The inner flow of the jet pump was regarded as the jet flow in confined and irregular space. Therefore, the flow is simplified as steady and incompressible flow in simulation and the energy exchange was neglected. The Realizable k-ε model with the double-precision computation was employed (Yuan, 2009). In the matter of near-wall-zone's

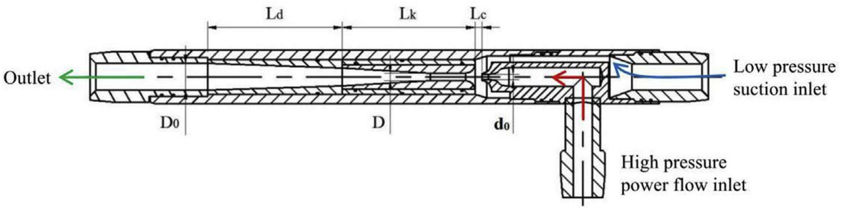

Fig. 1. Illustration of jet pump structure.