The design of Φ38 pump with strong corrosion resistance, equal diameter and depth

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Abstract：It designs a kind of Φ38 pump having a sand control ability, strong corrosion resistance, equal diameter and depth on the premise of meeting the needs of the special wells in oil fields. This pump can satisfied with the design requirements, such as well depth is at least 2500m, oil well pump plunger stroke is 3m and displacement is $49m^3/d$.

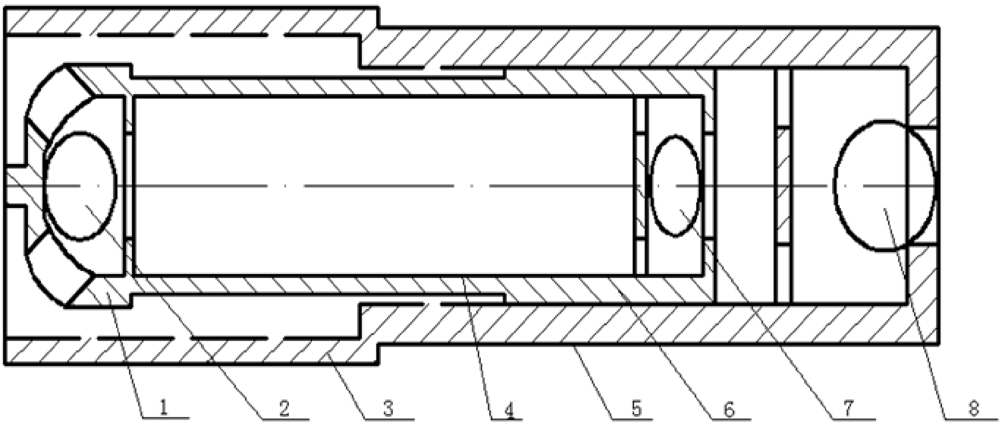
Introduction

The end stepped surfaces of conventional tube pump plunger are easily into sand. Because of sand accumulated, the capacity of traveling valve cover on the bearing is limited and plunger component parts are unable for corrosion resistance. This paper designs a new kind of pump with equal diameter and depth by analysis the disadvantages of traditional tubular pump. What's more, the new pump has a lot of advantages, such as simple structure, easy manufacturing, stronger bearing capacity, deeper well depth, as well as meeting the needs of the pump hung over $2500m$. Besides, it also can prevent sand from entering the barrel clearance between plunger and pump.

Overall structure scheme of Φ38 pump with strong corrosion resistance, equal diameter and depth

The overall structure of deep subsurface pump is shown in Figure 1.The pump composes of pump barrel assembly and the plunger assembly. Pump barrel assembly includes pump barrel, barrel coupling and fixed valve. But plunger assembly has up walk valve, plunger extension tube, plunger, down walk valve.

On the up trip, the sucker rod drives the plunger upward. At that time, up and down valves close. The volume below the plunger assembly pump cavity increases, while the pressure drops. All fixed valves open in the sinking pressure, and then the liquid in annular cavity between the tubing and casing goes into the pump chamber. The liquid column loads above plunger assembly tubing effect on up walk valve during the up time. The sucker rod drives the plunger downward during down stroke. Fixed valves close down pressure of the liquid column, while up and down valves open. The liquid in pump cavity beneath the plunger assembly is discharged to the top of the plunger assembly tubing.



1. up walk valve cover, 2. down walk valve cover, 3. tubing, 4. plunger extension tube, 5. pump barrel,6. plunger, 7. down walk valve,8. fixed valve

Figure1. Overall structure scheme of pump

The design of critical dimension

The design of the pump barrel length

The pump barrel length plays crucial role on Plunger stroke. This design requires pump plunger stroke reach 3m, so pump barrel length design should ensure that the pump plunger assembly having 300mm impingement distance after the collision. When go on upwards 3000mm, the length between the plunger and the pump cylinder seal is 1200mm.

The effective length of the plunger is $L_{zs}=1.2m$.The effective length of down walk valve cover is $L_{fz}=0.096m$. The effective length of down walk valve fitting is $L_{jt}=0.027m$. The effective length of pump barrel couplings at the bottom of the pump barrel is $L_{jg}=0.042m$.All lengths are determined by considering about their actual working conditions. Cylinder length can be calculated by the following formula.

$$\begin{aligned} L_b &\geq L_{zs}+L_{fz}+L_{jt}+L_f+S-L_{jg} \\ &=1.2+0.096+0.027+0.3+3.0-0.042\approx 4.6m \end{aligned} \quad (1)$$

In the formula: L_b—cylinder length（m）.

L_f—The design of impingement distance. It usually takes 0.3m.

S—plunger stroke. It usually takes 3m.

The design of extended pipe length

The extended pipe length decides whether walk valve to enter into pump barrel or not in the working process. Therefore, the extended pipe length needs to be decided after the pump barrel length is determined. The extended pipe length should have to make sure that down walk valve cover does not enter into the pump barrel when the pump is in a state of jet pump. The effective length of up walk valve connectors is $L_{sjt}=0.029m$ according to design requirement. So the length of extension tube L_g can be calculated by the following formula.

$$\begin{aligned} L_g &\geq L_b + L_{jg} - L_{zs} - L_{fz} - L_{jt} - 2\times L_{sjt} \\ &= 4.6 + 0.042 - 1.2 - 0.096 - 0.027 - 2\times 0.029 \\ &\approx 3.2m \end{aligned} \tag{2}$$

The design of the maximum downhole pump depth

The differences between the maximum downhole pump depths may cause the change of pump stroke, pump speed and load. The parts will break if downhole pump depth is more than the largest load that the minimum sectional area F_{min} of up walk valve cover can bear. Above all may lead to pump failure and unnecessary work over operation. It not only increases the operating cost, but also affects oil field production. As a result, the maximum downhole pump depth is an important basis for the bump's choice and design.

The stress states of pumps in the up and down stroke are also different. Two walk valve balls open in the up trip, but the gravity of fluid column affects on the pump barrel when it is closed. Besides, the gravity and the sinking pressure of the tail pipe act on pump barrel. The plunger component stress can be approximated at zero during this time. Two walk valve balls close in the down trip, but the gravity of fluid column acts on the up walk valve when it is opened. Otherwise, it affects inertial load and the sinking pressure of liquid column in the movement. The friction between the plunger and pump barrel also exists in the movement. At this point, the traveling valve carries the largest load, and pump barrel only under the gravity of the tail pipe.

The minimum cross-sectional area of up walk valve cover is in thread relief groove with M32×1.5. The outer diameter of thread relief groove is D_1=0.051m, and its inner diameter is d_1=0.0323m. The minimum cross-sectional area of up walk valve cover is calculated as follows.

$$F_{\min} = 3.14\times\left[\left(0.051/2\right)^2 - \left(0.0323/2\right)^2\right] = 1.222\times 10^{-3} m^2 \tag{3}$$

The largest load that up walk valve cover can bear：

$$\begin{aligned} P_{\max} &= p\left(D^2 - d^2\right) rH \frac{\left(1 + SN^2/1790\right)}{4} \\ &= 3.14\times\left(0.051^2 - 0.0323^2\right)\times 900\times 2500 \frac{\left(1+3\times 10^2/1790\right)}{4} \\ &= 3132 \end{aligned} \tag{4}$$

In the formula: r —oil density 900 kg/m^3.

N—pump speed in per minute, N = 10.

It can be known according to strength theory.

$$P_{\max} / F_{\min} \leq [d] \tag{5}$$

In the formula：$[d]$—Allowable stress for up walk valve, MPa , $[d] = d_s / n$,

d_s—The yield strength for the material of up walk valve, MPa.

n—safety factor , $n = 2.6$.

In order to improving the pump's corrosion resistance for H_2S、CO_2,the material of up walk valve cover is chosen as $3Cr13$, whose d_s is $540MPa$. Allowable stress for up walk valve can be gotten by taking d_s into formula (5).

$$[d]={d_s}/{n}={540}/{2.6}=207.7MPa$$

$$P_{\max}/F_{\min}=3132/(1.222\times10^{-3})<[d]=207.7Mpa$$

By all accounts, its strength is satisfied with the requirements, when the pump depth gets to $2500m$.

The calculation of theory displacement

The theory displacement is an important parameter to choose pump in the working operation. The theory displacement refers to the liquid capacity of pump barrel which is discharged in one stroke from plunger. It is equal to the column that plunger moves one stroke. The theory displacement of pump in a day can be calculated as follows.

$$Q_L=1440pR^2SN \tag{6}$$

In the formula: Q_L — The theory displacement of pump, m^3/d.

R — radius, m.

The theory displacement of pump can be gotten by taking $R=0.019m$ into formula (6) according to design requirement.

$$Q_L=1440pR^2SN=1440\times3.14\times0.019^2\times3.0\times10=48.96m^3$$

In conclusion，the designed pump can satisfied with the requirements that displacement of pump is $48m^3$ one day.

The calculation of the largest loss

The largest loss is a composite indicator to detect whether fit clearance size of pump is qualified. It can be calculated as follows.

$$Q=1.25\times10^{-2}\ \frac{pDd^3\Delta P}{mL} \tag{7}$$

In the formula: Q—The loss between pump barrel and plunger, $ml/\min$.

D—Pump nominal diameter, mm.

d—Pump unilateral clearance value, mm.

ΔP—Test pressure, $\Delta P=1\times10^7 Pa$.

m—The test medium is light diesel of number 10 dynamic viscosity, $m=4.25\times10^{-3}Pa\cdot S$.

L —The length of pump seal friction pair, mm.

Seeing from formula (7), pump leakage is simplified into a direct ratio with the third power of clearance. The larger clearance, the more miss.

Pump unilateral clearance value d is chosen as $0.044mm$ according to the range of scope fit clearance between plunger and pump barrel is $0.025 \sim 0.088mm$.

The loss between pump barrel and plunger can be gotten by taking the length of pump seal friction pair L is $1200mm$.

$$Q = 1.25\times10^{-2}\times3.14\times38\times0.044^3\times10^7/\left(4.25\times10^{-3}\times1200\right)=249$$

Conclusion

The design of $f38$ pump with strong corrosion resistance, equal diameter and depth is by design a longer tube column at the top of plunger, which can make the up walk valve unable to go into the pump barrel. This design has a number of advantages, such as increasing the size of up walk valve, improving the bearing capacity of the up walk valve, and enhancing the pump barrel length. Analysis and calculation indicate that the strength of parts can meet the design requirements of pump wells above 2500 m. Besides, plunger stroke, displacement, maximum loss all can meet the requirements to ensure the deep production needs. In addition, the plunger is designed for the same diameter to prevent the sand inflowing into the clearance between plunger and pump barrel or reduce the occurrence of the sand card so that it can prolong the pump inspection cycle and life time. This study extends the existing pump using range. It not only can be used in the well, but also can be used in wells with corrosive and sand .So it has a great engineering application value.

References

[1]Hongxiong Wang, Qi Zhang. Production process principle. Beijing: Petroleum Industry Press,1985.

[2]Xingbo Wan, Yingjun Wan. Production technical manuals. Beijing: Petroleum Industry Press ,1998.

[3]Huacan Fang,Wei zhou. The reliability design of oil drilling mechanical. Beijing: Petroleum Industry Press ,1998.

[4] The pump structure for combination of pump bobbin type and basic dimensions of main parts. Beijing: Petroleum Industry Press ,1998.

[5] Combination of bobbin type pump. Beijing: Petroleum Industry Press ,1998.