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# Study of Optimization Design on Oil-Water Separator of Injection-Production in the Same Well

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**Keywords:** Multiple cup flow separator, High water cut well, Oil-water separator, Optimization design.

**Abstract.** Based on the principle of fluid dynamics, multiple cup flow separator optimization design in the next article. We have carried out the optimization design on the parameters such as the number of holes, aperture classification, the size of the aperture and so forth. And give full play to the role of settling cup, can effectively shorten the length of the downhole oil-water separator, not only solves the problem of failing to scale application due to the existing separation effect is not good with high water cut well, more important is to save the production cost and operation cost.

## Introduction

Down hole oil-water separation (DOWS)[1,2] is a new technology, in the process of high water cut oil field development, which can solve high produced quantity and big separation quantity of oil well, at the same time, the huge investment and energy loss owing to injection water can be solved, the cost of handling waste water can be reduced, have remarkable economic and environmental effect. At present, there are two main down hole oil-water separation types[3,4]: swirl separation technology[5] and gravity separation technology[6]. Using the similar separation principle of multi-cup uniform flux gas anchor, multi-cup uniform flux oil-water separator is designed, the problem of the bad separation of existing down hole centrifugal oil-water separator and impossible large-scale application in high water cut well can be solved.

## Multi-cup Uniform Flux Oil-Water Separator

On the central tube of multi-cup uniform flux down hole oil-water separator (Figure 1), more settling cups are installed[8] (Figure 2), in the settling cups, there are leakage sand holes which are used for excluding solid impurities, liquid inlets are drilled at the central tube near the inside bottom of every settling cup, the central tube is connected to some roots, between which a protective body is installed, the central tube is liquid inlet channel of backwater and injection water, the annulus between tubing and casing is liquid inlet channel of produced liquid, under which is the plug.

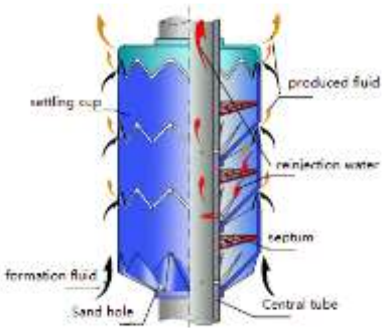
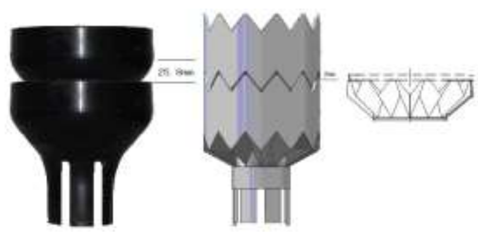



Figure 1. Oil-water separator.



Ordinary bowl settling cups Crown settling cups

Figure 2. Settling cups of different types.

The separator is connected to the lower portion of the injection pump, the formation produced fluid enters the settling cup first, which is separated into backwater of higher water cut and produced fluid of lower water cut, and then produced fluid enters the pump through the liquid inlet, according to maximum production in the upstroke of pump, the area of cross section of the liquid inlet is calculated precisely, which makes the liquid volume of each cup entering the central tube of oil-water separator approximately equal.

## The Design Method of Process Parameters of Injection-Production in the Same Well

Owing to the density difference between oil and water, the formation produced liquid flows settling cups to realize natural settlement separation, after separation, the backwater of higher water cut enters central tube, then is produced by injection pump, but the produced liquid of lower water cut enters the annulus between tubing and casing, which is lifted to the ground by producing pump. In all the separation process, when the injection pump is pumping every time, the liquid quantity entering the every settling cup is approximately equal, which is ensured. Therefore, uniform flux parameter design hydraulic calculation analysis is carried out.

### The Friction Pressure Difference Inside the Central Tube

$$\Delta p_f = \rho g h_f = 87.66 \frac{\upsilon^{0.25}}{D^{4.75}} Q_0^{1.75} L \qquad (1)$$

where: $\Delta p_f$ is friction pressure difference inside the central tube of separator, Pa; ρ is density of produced liquid, $kg/m^3$; $h_f$ is head loss inside the central tube, m; $Q_0$ is daily handling capacity of separator, $m^3/d$; υ is kinematic viscosity of produced liquid, $m^2/s$; D is central tube inner diameter of separator, m; L is central tube length, m.

### The Inner and Outer Pressure Difference of Central Tube

$$\Delta p = \rho g h_j = \rho g \times \xi_{micropores} \frac{v^2}{2g} \qquad (2)$$

where: Δp is inner and outer pressure difference of central tube of separator (Working pressure difference), Pa; $h_j$ is the orifice local head loss, m; $\xi_{micropores}$ is local resistance coefficient, which can be determined by the data analysis is 1.5; v is orifice velocity, m/s; α is the orifice laminar flow and orifice interference correction coefficient, according to the results of numerical simulation of flow, it is 8.

### The Residence Time of the Produced Liquid in Each Cup

$$t=V/(mq) \qquad (3)$$

where: t is residence time of the produced fluid in the settling cups, s; V is settling cup volume, $m^3$; q is single orifice inlet flow rate, $m^3/s$; m is number of orifice per layer.

It should be noted here that: the results of laboratory tests show that the minimum residence time for effective oil-water separation is 150s, in some cases, there may be the residence time of produced fluid is less than the minimum residence time close to the lower part of some separator, the ratio the inlet liquid flow rate which the residence is in a relatively short time and total liquid flow rate (capacity) is known as low stop flow rate time percentage, referred to as the "low stop percent".

## Optimization Example

The water content of the produced liquid of a high water cut oil well in Daqing oilfield is about 90%,viscosity is $2.9\times10^{-6}m^2/s$, daily handling capacity $Q_0$ is $80m^3$ and $60m^3$ respectively, Inner diameter of anchor pipe *D* is 38mm, the volume of anchor bowl *V* is 0.2L, the spacing of anchor bowl *l* is 0.045m, length of anchor pipe *L* is 30~80m. By means of above theory, the optimization software system is programmed by using VB6.0, the programming diagram is as shown in Figure 4. According to the need, different orifice diameter series and differential are set, at the same time, different open orifice numbers and orifice number differential can be set, and the residence time distribution can be directly displayed graphically, which makes the design software of separator more flexible and practical.

So, aiming at the produced liquid amount of 80m$^3$/d oil well, design scheme is as follows.

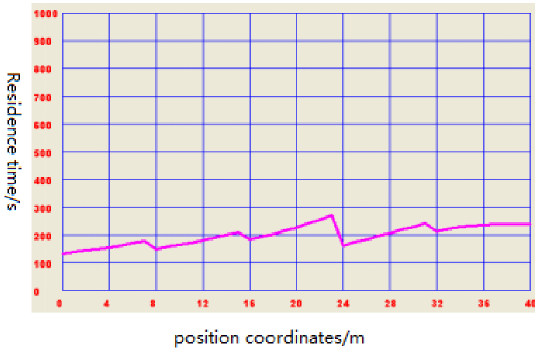
(1) The proposed design scheme for the daily handling capacity of 80m$^3$.

Anchor pipe length 40m, which is divided into each section of 8m.

Five level aperture:

The first section is 0.9mm; the second section is 1mm;...; the fifth section is 1.3mm.

Two level orifice number: The orifice number of the first section 8m is 4; The orifice number of the second section 8m is 4; The orifice number of the third section 8m is 4; The orifice number of the fourth section 8m is 6; The orifice number of the fifth section 8m is 6.




Anchor bowl volume 200ml
Anchor bowl distance 45mm
The diameter of the central tube 38mm
Number of segments 5
Result: residence time:139s
residence time:240s
Below the minimum residence time into flow percentage:10.3%

| | First section | Second section | Third section | Fourth section | Fifth section |
|---|---|---|---|---|---|
| **Tube length** | 8 | 8 | 8 | 8 | 8 |
| **Hole diameter** | 0.9 | 1.0 | 1.1 | 1.2 | 1.3 |
| **Hole numbers** | 4 | 4 | 4 | 6 | 6 |

Figure 3. Distribution diagram of residence time of corresponding upper 40m from suggesting project.

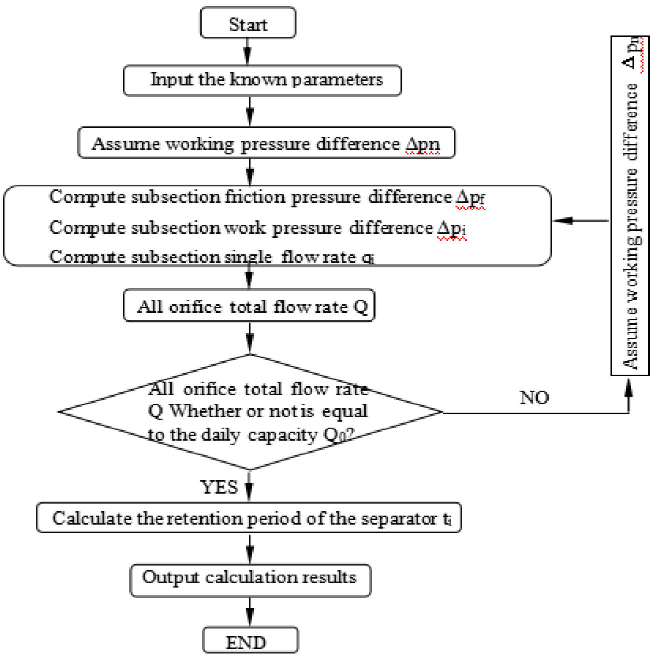



Figure 4. Computing diagram of residence time.

(2)The proposed design scheme for the daily handling capacity of 60m$^3$.

Anchor pipe length 36m.

Three level aperture:

The aperture of first section 12m is 0.9mm; the aperture of second section 12m is 1mm; the aperture of the third section is 1.1mm.

Three level orifice number:

The orifice number of the first section 12m in every layer is 4;

The orifice number of the second section 12m in every layer is 6;

The orifice number of the third section 12m in every layer is 8; Its residence time is greater than 150s, the specific distribution is as follows:


Nissan fluid volume 60m3
The moisture content 95
Anchor bowl volume 200ml
Anchor bowl distance 45mm T
he diameter of the central tube 38mm
Number of segments 3

Result: residence time: 184s
residence time: 286s
Below the minimum residence time into flow percentage: 0%

Figure 5. Distribution diagram of residence time of corresponding upper 36m from suggesting project.

Table 1. Pipe section parameters of corresponding upper 36m from suggesting project.

| | First section | Second section | Third section |
|---|---|---|---|
| Tube length | 12 | 12 | 12 |
| Hole diameter | 0.9 | 1.0 | 1.1 |
| Hole numbers | 4 | 6 | 12 |

## Conclusion

The injection-production process technology research in the same well is the China Petroleum and Natural gas stock company scientific research project, which has now entered the field trials, the problem of the bad separation of existing down hole centrifugal oil-water separator and impossible large-scale application in high water cut well can be solved. By using the theory of fluid dynamics, optimization design of multi-cup uniform flux separator has been studied, the parameters like the aperture size, grading and opening numbers are optimized design, in each part of settling cup, the residence time of produced liquid is more than 150 seconds, which can give full play to the role of each settling cup, the length of down hole oil-water separator can be shortened effectively, the production cost and operation cost can be also saved.

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