Main devices design of submarine oil-water separation system

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Abstract. In the process of offshore oil production, in order to thoroughly separate oil from produced fluid, solve the environment problem caused by oily sewage, and improve the economic benefit of offshore drilling, from the perspective of new oil-water separation, a set of submarine oil-water separation devices were designed through adsorption and desorption mechanism of the polymer materials for crude oil in this paper. The paper introduces the basic structure of gas-solid separation device, periodic separation device and adsorption device, and proves the rationality and feasibility of this device.

1. Introduction
The offshore separation technology has a broad development prospect. A offshore separation system suitable for the exploitation of local offshore oil fields will greatly increase the economic benefit of the offshore oil fields. Producing water of oil wells is usually a difficult problem to avoid during the development of offshore oil and gas fields [1]. Generally, as the mining continues, water production will gradually increase. The treatment expense of high-water crude oil is often also a large part of the cost of offshore oil and gas field development, and reducing cost of high-water crude oil is becoming more and more important.

Generally, when water-cut is low, the production fluid of the submarine production well is pumped through pipeline to the offshore platform to realize the oil, gas and water phases separation. When the water-cut reaches more than 15%, it is processed in the three-phase separator under the offshore. Offshore oil-water separation system can greatly reduce static head of riser and water (ground) surface separation device work load [2-4]. Not only it needs to scale transformation, but also reduces the wellhead back pressure. The water injection system can even be used to inject separation water into the stratum directly, replacing the conventional water injection solution. Compared with the existing offshore oil-water separation device, the oil-water adsorption separator is more practical, which can satisfy the oil-water separation technology that the existing device cannot handle [5]. Meanwhile, the volume scale is less than gravity separation device, hydraulic cyclone separation device and so on, and its energy consumption is relatively low, it also can be used in the deeper waters.

2. Oil-water separation system
Due to large sea bottom pressure, vertical height is low, so the device mainly places on the horizontal, the general principle is shown in Figure 1. Well production flows into the gas-solid separation equipment through the liquid pipe. And gas and a small amount of residual solid phase will be separated isolated from production liquid. When separated oil-water mixture flows into period separating device in the period separating device, the oil-water mixture is evenly divided into two periods to inject into adsorption device for oil-water separation. In the adsorption process of the device, water, through the adsorption device and liquid separating device, is re-injected by pump. In the desorption process, oil,
through liquid separating device, is fed into the platform through pump.

![Diagram of submarine oil-water separation system]

**Figure 1.** A simplified flow diagram of submarine oil-water separation system

### 3. Gas Solid Separation Equipment

The separation equipment is packaging in a large box. After putting device in seabed, automatic flange connector of offshore pipeline connects the equipment and pipeline. It can avoid works in the bottom of the sea, to enhance the safety of construction. Production liquid flows into the equipment through the production liquid inlet pipe, as is shown in Figure 2. There is a separator in the entrance that makes production liquid entry evenly. Solid phase separation sieve is fastened around the separator by fitting. When solid phase achieve to a certain number that affect the normal production of the equipment, the feedback device inform the ground staff replacement of solid phase separation sieve.

When the oil-gas mixture flow into the production liquid inlet pipe, it dispersed uniformly at the separator. As the liquid entering into the separator, at once volume becomes larger, the flow rate and the buffer pressure decreases, oil flow disperse, gas is easily dispersed from liquid. Because the gas density is lower than liquid, gas rise and move along the upper separator. The separated fitted with separating cylinder at the outlet pipe that equipped with multi-layer stainless steel wire mesh. When separated gas rise to the top of the device, it is contact with stainless steel wire mesh. Due to the adhesion of liquid, the tiny droplets in the gas are separated once more and attached to the stainless steel wire mesh surface. Then they drop, outlet gas is collected on platform through the pipe.
Figure 2. A sketch of gas solid separation equipment

1-gas solid phase separation equipment case; 2-flange; 3-the produced liquid inlet pipe; 4-the separation of the head; 5-solid phase separation sieve; 6-the oil-water surface; 7-outlet gas pipe; 8-separator; 9-float connecting rod mechanism; 10-oil-water pipe

The liquid that solid phase is separated through solid phase separation sieve gathered at the bottom of the device with the dropped liquid trapped at separator. And it is formed slight change of the liquid surface according to the well liquid producing capacity. Float connecting rod mechanism will monitor the liquid surface and the change of water content. It could feedback to the ground system and adjust the subsequent operation period of separation device according to the liquid producing capacity. Thereby, the adsorption effect of the adsorption device is effectively performed, energy consumption is reduced and the service life of the device is improved.

The oil-water mixture at the bottom of the device flows into the period of separation device through the oil-water pipe to subsequent separation.

4. Period of Separation Device
Due to the existence of adsorption and desorption period in the follow-up adsorption device, in order to improve the processing ability of the device, oil-water mixture continuously inflow is divided into two parts for processing, as is shown in Figure 3.

Figure 3. A sketch of period separation device

1-oil-water pipe; 2-turntable; 3-connecting shaft; 4-period separation device box; 5-gasket ring; 6-piston; 7-distributing oil-water pipe

The oil-water mixture flows into period of separation device through the oil-water tube. In the device, liquid will be evenly separate to two oil-water pipes at regular intervals. Rotary non-uniformly rotation in cam structure, form shortest period rotation of total amount of adsorption and desorption time. The piston movement in the period of separation device is driven by a connecting rod. In the periodic contact of piston and the sealing ring and the piston interruption, oil-water mixture periodic flow in different oil-water pipes.

In the total separation equipment for monitoring of fluid production and water cut, with reasonable
calculation and achieving adsorption device full potential to the premise, the operation period of separation device will be increased or decreased, to reduce energy consumption and increase the service life of the equipment.

5. Adsorption device
The oil-water mixture passes through the periodic separation device and enters the adsorption device, the structure shown in Figure 4. This part is the core part of the separation equipment, two absorption barrel of it process inflow oil-water mixture with alternate adsorption and desorption.

![Figure 4. A sketch of adsorption device](image)

1-distributing oil-water pipe; 2-air connected valve; 3-adsorption device box; 4-nozzle; 5-desorption device; 6-adsorption rod; 7-oil-water period pipe

The oil-water mixture, distributing oil-water pipe, evenly sprays adsorption device section from nozzle. In the air valve open, the internal device is communicated with the outside and fluids allow to free flow of in the longitudinal direction of the small pores. Under the fixed condition of desorption device, adsorption rod distribute interface evenly with the shape of hexagonal, as shown in Figure 5, and the working principle is shown in Figure 6.

![Figure 5. A sketch of desorption device section](image)

1-adsorption rod; 2-desorption device and support structure
Figure 6. Working principle of Adsorption device

Figure a is the initial stage of the device in the adsorption and desorption period; figure b is full of oil in the device after it is filled with produced liquid; Figure c is the process of starting the drainage of the device; Figure d is the process of desorption after the drainage is finished.

In order to separate the oil and water of periodic flows, liquid separating device could be added here, its operation period is controlled by separation device. In the turntable, oil and water channel present alternative distribution features on the axial direction, and the rotation stopping time is the adsorption period and desorption period time.

Rotation period of the device is controlled by cam, it respectively stays in adsorption and desorption period for different rotation angles.

In adsorption period, oil is absorbed on adsorption rod and only water flow out of liquid pipe, and the rotation angle of the device is shown in Figure 7.

Figure 7. A sketch of liquid separating device

1-oil-water device tube; 2-water channel; 3-oil channel; 4-shaft; 5-rotating wheel; 6-oil pipe; 7-the shadow of side water pipe; 8-the shadow of side oil pipe; 9-water pipe
The oil and water channel have elevation differences in the axial direction with staggered distribution, and the water inflow from the water pipe channel.

When it goes into desorption period after adsorption period, the wheel rotates 180 degrees in a short time along the axis, and the rotation angle of the device is shown in Figure 8. The water inflow from the water pipe channel.

Figure 8. A sketch of oil channel connected graph

6. Conclusions
Through the above comparison, it can be found that the adsorption oil and water separator is better than other underwater oil-water separation technology, which has the advantages of high efficiency, low energy consumption and small equipment. However there are also shortcomings with adsorption oil-water separator: high performance requirements of adsorption material (adsorption material cost is relatively high), and the process is mainly aimed at the high of oil-water separation (water cut is more than 90%).

With the progress of science and technology, the continuous development of material technology, low cost of research and development, it will become possible of high performance of the crude oil adsorption materials. The success of research and development plays a promoting role to industrial application of adsorption separation technology, and technology development has laid a solid foundation. Meanwhile it provides favorable conditions for the marine oil and gas field development to the deep sea.

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Reference
[1] Tie-hui Piao, Ying-hui Liu, et al. Assessment of Marine oil pollution treatment methods, J. China Population Resources and Environment, 2012.
[2] Yi Ding, Jia-qing Cheng. Key technical analysis of oil and water separation in deep water, J. Journal of filtration & separation, 2009, 19(2): 10-15.
[3] Zuo-wan Yang. A study on the optimal design of improving the effect of three-phase separator, D. Xi’an: Xi’an Shiyou university, 2013:5-8.
[4] Min Zhang, Hui-xin Yuan. Theory and Application of Coalescence in Hydrocyclon, J. Fluid Machinery, 2003, 31(5): 31.
[5] Tie-zhu Zhang. The Study on Spilled Oil Recovery Equipment and Measure in Shengli Oilfield, J. Environmental Protection of Oil and Gas Fields, 2002, 12(31).