

Investigation of Pipe Separation Technology in the Oilfield

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Abstract. Crude oil separating is an important technological process in the petroleum industry. Pipe separation technology (PST) is a new kind of separating method in oil-water-gas separation. To compare with conventional gravity separators, the new separator based on PST is low weight, low cost, efficient and convenient to maintain. This paper introduces this new compact separator, technological process and performance test. The test results show that the compact separator has good separating effect. When the water-cut inlet is from 50% to 60%, and the mixture flow rate is from 40 t/hr to 100 t/hr, the water-cut in oil outlet is less than 5%, and the oil-cut in water is less than 100 mg/l.

Introduction

Pipe separation technology (PST) is a new kind of separating method in oil-water-gas separation. In the last few years, pipe separator has become a new generation of centrifugal oil-water separator, and has been successfully used in waste water treatment. Pipe separator is simple structure, small size, light weight and low operating cost.

Institute of mechanics, Chinese academy of sciences, have researched PST from 1999. The research on the PST includes theoretical, experimental, setting up multiphase loop facility and separating device [1]. They developed a combined separator based on the principles of gravity, centrifugation and expansion. The combined separator is high efficiency and quick separation [2]. Some theoretical and experimental research for the oil-water separation in the helical pipe is developed [3, 4].

A new combined high efficiency compact separator of oil-gas-water is designed and made in 1/10 scale since 2001. The separator which utilized the principles of gravity, expansion and centrifugation is designed into a novel structure. Its key components are helical pipes, T-shaped pipes etc [5, 6]. The bulk and weight of this new separator is less 30% than the conventional separator of the same handling capacity. Since 2005, the applications of multi-bifurcated pipes in separating gas-liquid and liquid-liquid two phase flows have been investigated [6]. The numerical and experimental study on cylindrical hydro-cyclone in oil-water separation was developed [7, 8]. The results can be used to optimize the structure of cylindrical cyclones and provide some guidance for the use of PST. This paper introduces the PST. It includes technological process, performance test, and result analysis.

Working principle

a) Gas-liquid separation

The cyclone is used to separate gas and liquid. The separation is achieved on centrifugation and gravity effects. It is a conventional gas-liquid separation method.

b) Separation in T-shaped pipes

The separation in T-shaped pipes is achieved only on gravity effect. It is used to separate oil and water or gas and liquid at low velocity and large density difference. The rising of oil droplets in the T-shaped pipe is governed by Stokes's Law. This function, simply stated is shown in the following equation:

$$V_p = \frac{g}{18} (D_p - D_c) \frac{d^2}{\mu}$$

Where: V_p = droplet settling velocity, m/s
 g = gravitational constant, 9.80 m/s²
 D_p = density of particle (droplet), kg/m³
 D_c = density of continuous fluid, kg/m³
 d = diameter of particle, m
 μ = absolute viscosity of continuous fluid (water), cp

c) Cylindrical hydro-cyclones

This separation is achieved on centrifugal effect. Oil and water enter the vertical separator section through the reducing area nozzle which increases flow velocity. The swirling motion in the cylindrical pipe produces a centrifugal separation, an oil-rich stream exits through the top overflow and a water-rich stream leaves the system through the bottom underflow. The separating velocity of oil droplets in a pipe is governed by force of centrifugation. It stated is shown in the following equation:

$$F_c = \frac{\pi}{6} d_p^3 D_p \frac{u_t^2}{r}$$

Where: F_c = force of centrifugation, N
 d_p = diameter of particle (droplet), m
 D_p = density of particle (droplet), kg/m³
 u_t = tangential velocity of continuous fluid (water), m/s
 r = distance between of particle and axis pipe, m

Design parameters of new type separator

The new separator consists of pipe system and tank system. The tank has two functions. One function is to buffer, the other is to separate again. It is 12m long and 2.4m diameter. The design parameters are:

- Gas flow rate is 17000-20000 m³/d
- Liquid (oil and water) flow rate is 3700 t/d
- Liquid concentration in gas outlet is less than 50 mg/m³
- Oil-cut in water outlet is less than 1000 mg/l

Test objectives

There are three major objectives of this test. The first is to investigate actual efficiency and handling capacity. The second is to inspect separation effect, especially, oil-cut in water outlet. The third is to evaluate performance of PST. The separation of oil and water was key point this time. The effect of gas separation was not inspected, and not evaluated.

Technological process

The test fluid is the crude oil which comes from the old production line of Boxi oilfield. Figure 1 is the process flow diagram. The test fluid passes through the new separator first, and then flows into storage tank. Finally, it flows back to the old production line. The new separator consists of separating device of gas and liquid, T-shape pipe and cylindrical hydro-cyclone. The storage tank is divided into three parts. They are water room, mixing room and oil room. The water room stores water-rich stream from T-shape pipes. The mixing room stores the mixture of oil and water. The oil comes from water room and the water comes from cylindrical hydro-cyclone. The oil room stores oil from mixing room and cylindrical hydro-cyclone. The new separator picture in the oilfield is shown in figure 2.

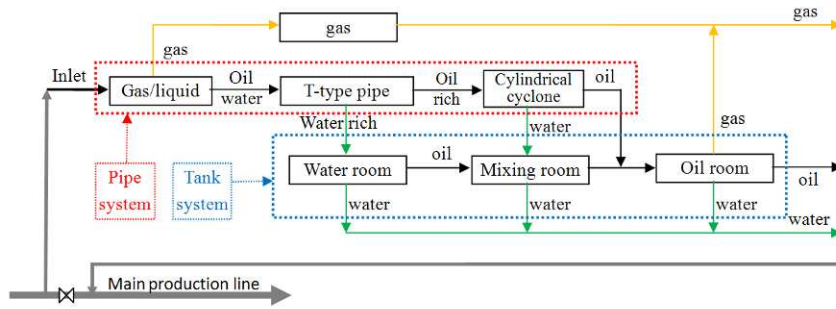


Fig. 1 The process flow diagram of test

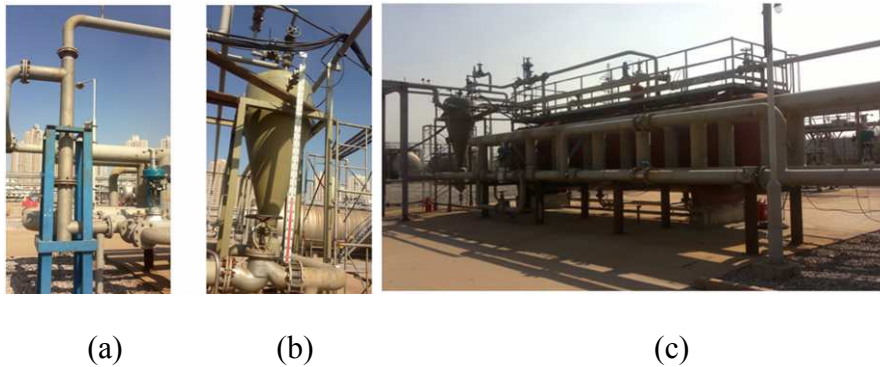


Fig. 2 The device of the new separator (a) cylindrical hydro-cyclone; (b) device of gas and liquid; (c) T-shaped pipes and storage tank.

Test results and analysis

The test sample and analysis report were relegated to third party. The third party was responsible for sampling water and oil, and providing analysis result. There were 25 samples in this test. The sampling positions located at old production line, oil and water outlets at the old separator and new separators. Table 1 shows the results of field test. By the way, the inlet pressure is 0.68 MPa. The inlet temperature is 65°C. The mixture flow rate is from 40 to 100 t/hr. The inlet water-cut is from 51.8 to 64.2%.

Table 1 The results of field test

Item	Qi,t/hr	Ki,%	Kwater old,%	Kwater new,%	Koil old,mg/l	Koil new,mg/l
1	40	51.8	18	2.8	486	26.4
2	50	60.6	20	3.2	578.2	76
3	70	64.2	25	4.8	542.3	68
4	80	58.6	24	4.7	526.8	54
5	100	54.7	21.1	4.1	506.6	36.6
Average	68	57.9	21.6	3.9	527.9	52.2

Where Qi = inlet mixture flow rate, t/hr

Ki = inlet water-cut, %

Kwater old = water-cut in oil outlet in the old separator, %

Kwater new = water-cut in oil outlet in new separator, %

Koil old = oil-cut in water outlet in the old separator, mg/l

Koil new = oil-cut in water outlet in new separator, mg/l

a) Water-cut in oil outlet

From analysis report, the results of the old and new separators are compared. In the old separator, the maximum of water-cut in oil outlet is 25%, the minimum is 18%, and the mean value is 21.6%. But in the new separator, the maximum of water-cut in oil outlet is 4.8%, the minimum is 2.8%, and the

mean value is 3.9%. The water-cut in oil outlet of new separator is cut down 81.9%. Figure 3 shows the comparison of the water-cut in oil outlet between two separators. (a) is the water-cut in oil outlet along with inlet mixture flow rate. (b) is the water-cut in oil outlet along with inlet water-cut.

b) Oil-cut in water outlet

In the same way, the oil-cut in water outlet is from 486 to 578.2 mg/l in the old separator. It is from 26.4 to 76 mg/l in the new separator. It is cut down 90.1% in the new one. Figure 4 shows that the comparison of oil-cut in water outlet between two separators. (a) is the oil-cut in water outlet along with inlet mixture flow rate. (b) is the oil-cut in water outlet along with inlet water-cut.

Because of the actual production situation, the maximum of liquid flowrate was only 100 t/hr rather than 3700 t/d (=154.2 t/hr). But the analysis results showed that design parameters were up to grade. Although the flowrate was not be maximum, the indication correspond with design parameters.

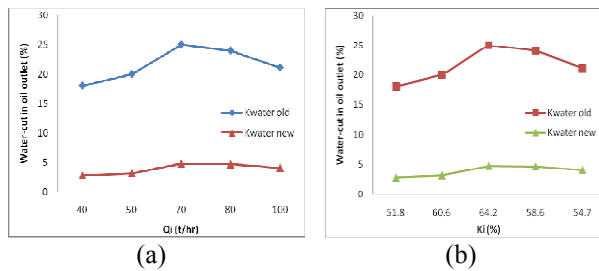


Fig. 3 The comparison of water-cut in oil outlet between two separators (a) The water-cut in oil outlet along with mixture inlet flow rate; (b) The water-cut in oil outlet along with inlet water-cut.

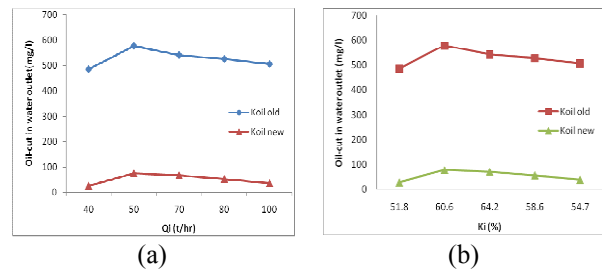


Fig. 4 The comparison between oil-cut in water outlet between two separators (a) The oil-cut in water outlet along with inlet mixture flow rate; (b) The oil-cut in water outlet along with inlet water-cut.

Conclusions

The performance test shows that PST is a good method to separate mixture of oil water and gas. The water-cut in oil outlet is less than 5%, and the oil-cut in water outlet is less than 100 ppm. They are within the ranges of test parameters. The new compact separator was designed by PST has good separating effect in the oil-water separation. The test results illustrate that the pipeline separator based on PST is going to have a good prospect. Pipeline separator is simple structure, small size, light weight, and low operating costs. It will bring revolutionary change in oil-water-gas separation.

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