Experimental Study on Inlet Structure of the Rod Pump with Down-hole Oil-water Hydrocyclone

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Abstract

For the problem of high water cut oil producing well, the technology which the oil-water is separated and injected to down hole can reduce cost price. The down-hole oil-water separation system is composed of double fluid flow pump, oil-water hydrocyclone and oil lift pump. This system runs well on site. Experimental study found that the average separation efficiency of hydrocyclone with rectangular section tangent inlet and flow deflector can reach 99.4\%, what’s more, the average reduction rate of separation efficiency is only 0.25\% in continuous flow and it decreases slowly with the ratio of split ratio divided by oil content increasing. Compared with Archimedes spiral inlet, the former’s manufacture technology is simpler and suitable to the rod pump’s down-hole oil-water separation system.

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Keywords: down-hole oil-water separation; hydrocyclone; separation efficiency

1. Introduction

Recently, the most oil fields in China have been entering into the middle and high water cut stage of development, and the water cut rates of part of the oil fields have been more than 90\%, so it is particularly important to reduce the equipment investment, the costs of operation and maintenance, and relieve the environmental pressure caused by water leaks and emissions [1-2]. By using the down-hole oil-water separation...
hydrocyclone and injection technology, we can extract and inject most of the water of the high water content crude oil at the bottom of the same well, and reduce oil production costs.

The down-hole oil-water separation system is composed of double fluid flow pump, oil-water hydrocyclone and oil lift pump. The separation efficiency of hydrocyclone is decided by the structure of hydrocyclone and the revolving intensity of the liquid stream in the hydrocyclone [3]. The inlet is the first passage of the hydrocyclone. It is indicated by experiment that the pressure loss of inlet occupy about 40% of the whole pressure loss [4-5]. The structure of inlet influences the flow field distribution and separation efficiency directly. The reasonable structure of inlet can make the pressure loss mainly locate in the cavity of hydrocyclone.

Based on the numerical simulation of flow field of hydrocyclone, we design a hydrocyclone with rectangular section tangent inlet and flow deflector, and have laboratory experiment.

2. Influence of inlet structure on separation efficiency of hydrocyclone in continuous flow

The main structure of the hydrocyclone with cylinder type overflow pipe in experiment is the same in size. And we use the hydrocyclone with rectangular tangential inlet, and the hydrocyclone with Archimedean screw inlet, and the hydrocyclone with rectangular tangential inlet and flow deflector to run experiment experiments (Fig.1)

(a) rectangular tangential inlet (b) Archimedean screw inlet (c) rectangular tangential inlet with flow deflector

Fig.1 the structure of hydrocyclone used in experiment

2.1. Experimental facilities and process

(1) Experiment facilities
Hydrocyclone(Fig.2); 50D8×5 centrifugal pump; DE-HSUL28 water in oil analyzer; LWGY-25 turbo flow meter; 723 ultraviolet spectrophotometer.

Fig.2 the structure of hydrocyclone (the unit of length is mm)

(2) Physical property of crude oil
Density: 902 kg m⁻³ (50℃)
Viscosity: 15.2 mPa·s (50℃, 1atm)

(3) Flow chart of experimental processing
Fig.3 depicts the flow chart of experimental processing. Mix crude oil and water with a certain proportion in circulating water tank, and heat to 50℃, and then separate the mixture with hydrocyclone. In the process of separating them, very low oil cut water pass the under flow pipe to enter into the circulating water tank, and low water cut oil pass the overflow pipe to enter into the circulating water tank,
and the liquid mixes again. Install sample points at the inlet pipe, overflow pipe, and underflow pipe to take samples at any time.

When we do experiments, connect pipes, open all valves, run centrifugal pump, adjust the flow rate of inlet to about 4.5m³/s, and adjust the split ratio to about 35%. After the liquid flows steadily, record the pressure, flow rate, take sample and calculate split ratio and separation efficiency.

(4) Data gathering

The oil concentration of inlet and overflow is measured by water in oil analyzer, and that of underflow is measured by ultraviolet spectrophotometer.

![Fig.3 The flow chart of experimental in continuous flow](image)

2.2. Experimental data analysis

Record experimental data once every 5 minutes under the same experimental condition, and calculate the average value per five recorded data. Experimental result shows as fig.4.

![Fig.4 Influence of inlet structure on separation efficiency of hydrocyclone in continuous flow](image)

Fig.4 shows that separation efficiency of hydrocyclone with rectangular tangential inlet is lowest, only 93.5%, and the separate efficiency has major fluctuation when the oil concentration of inlet varies. Because the entering fluid at the inlet of hydrocyclone and the revolving fluid at the cylinder part of hydrocyclone can cause disturb. The separation efficiency of hydrocyclone with Archimedean screw inlet can reach 98.4%, because the connections between Archimedean screw and cavity of hydrocyclone are smooth, the flow path of inlet descends the breaking of liquid droplet. The separation efficiency of hydrocyclone with rectangular tangential inlet and flow deflector is highest, reach 99.4%, and the separate efficiency has slight fluctuation when the oil concentration of inlet varies. Because the flow deflector at
inlet can make the fluid circulate downward. And the fluid is under the inlet of hydrocyclone when it turns 360°. Hydrocyclone with rectangular section tangent inlet and flow deflector can avoid the disturbance that is generated by the entering fluid at the inlet of hydrocyclone and the revolving fluid at the cylinder part of hydrocyclone, and decline the energy consumption when fluid pass the inlet.

3. Influence of inlet structure on separation efficiency of hydrocyclone in intermittent flow

The down-hole oil-water separation system whose motive force is provided by a beam pumper on the ground with rod is composed of double fluid flow pump, oil-water hydrocyclone and oil lift pump.

On the upstroke, the high water content crude oil is separated by hydrocyclone. And on down stroke, there is no fluid entering into the hydrocyclone. So the crude oil flow in hydrocyclone is intermittent flow.

In order to research the influence of intermittent flow on separation efficiency, install ZCS-25 electron magnetic valves and back pressure control valve on the pipes (Fig.5). The electron magnetic valves up/down 4 times every minute (The situation of valve A and that of valve B are opposite.).

![Flow chart of experimental setup](image)

When we do experiments, first, open all valves except valves B, run centrifugal pump, adjust the flow rate of inlet to about 4.5m³/s, adjust the split ratio to about 35%. After the liquid flows steadily, record the pressure, flow rate, take sample and calculate split ratio and separation efficiency. Second, switch electron magnetic valves periodical. After the liquid flows steadily, record the pressure, flow rate, take sample and calculate split ratio and separation efficiency. The experimental data is in table 1.

Table 1 shows that the separation efficiency intermittent flow is lower than that of continuous flow. The average rate of decline of hydrocyclone with rectangular tangential inlet is 1.1%, and the average rate of decline of hydrocyclone with Archimedean screw inlet is 0.43%, and the average rate of decline of hydrocyclone with rectangular tangential inlet and flow deflector is lowest, only 0.25%.

Fig.6 shows that the rate of decline of separation efficiency is decreasing with the ratio of split ratio divided by oil content increasing. The decline trend of hydrocyclone with rectangular tangential inlet and flow deflector is slower than that of other hydrocyclones.
Table 1 the experimental data

| Entrance Type                  | Flow rate of inlet (m³/h) | Split ratio (%) | Underflow (continuous flow)(mg/L) | Underflow (intermittent flow)(mg/L) | Separation efficiency of Continuous flow (%) | Separation efficiency of Intermittent flow (%) | Decline rate of separation efficiency (%) |
|-------------------------------|---------------------------|----------------|-----------------------------------|--------------------------------------|---------------------------------------------|-----------------------------------------------|------------------------------------------|
| Rectangular tangential inlet  | 4.2                       | 35.71          | 3.4                               | 2250.8                               | 93.38                                       | 92.57                                         | 0.86                                     |
|                               | 4.7                       | 34.04          | 4.9                               | 3155.6                               | 93.56                                       | 92.79                                         | 0.82                                     |
|                               | 4                         | 35.00          | 6.2                               | 4085.8                               | 93.41                                       | 92.35                                         | 1.13                                     |
|                               | 4.5                       | 33.33          | 8.7                               | 5802.9                               | 93.33                                       | 92.21                                         | 1.2                                      |
| Archimedean screw inlet       | 4.8                       | 35.42          | 10.3                              | 6880.4                               | 93.32                                       | 92.36                                         | 1.02                                     |
|                               | 4.3                       | 34.88          | 3.7                               | 603.1                                | 98.37                                       | 98.01                                         | 0.36                                     |
|                               | 4.8                       | 35.42          | 5.1                               | 688.5                                | 98.65                                       | 98.16                                         | 0.39                                     |
|                               | 4.4                       | 34.09          | 7.4                               | 954.6                                | 98.71                                       | 98.21                                         | 0.51                                     |
|                               | 4.1                       | 36.59          | 8.5                               | 909.5                                | 98.93                                       | 98.55                                         | 0.38                                     |
|                               | 4.7                       | 34.04          | 9.8                               | 842.8                                | 99.14                                       | 98.61                                         | 0.53                                     |
| Rectangular tangential inlet  | 4.2                       | 33.33          | 3.1                               | 195.3                                | 99.37                                       | 99.16                                         | 0.21                                     |
| in net with flow deflector    | 4.5                       | 35.56          | 4.7                               | 164.5                                | 99.65                                       | 99.41                                         | 0.25                                     |
|                               | 4.8                       | 35.42          | 5.8                               | 516.2                                | 99.11                                       | 98.87                                         | 0.24                                     |
|                               | 4.1                       | 36.59          | 7.9                               | 608.3                                | 99.23                                       | 98.96                                         | 0.27                                     |
|                               | 4.4                       | 34.09          | 9.7                               | 543.2                                | 99.44                                       | 99.22                                         | 0.22                                     |

Fig. 6 The rate of decline of separation efficiency

4. Conclusion

(1) The separation efficiency of hydrocyclone with rectangular tangential inlet and flow deflector is highest, and the separate efficiency has slight fluctuation when the oil concentration of inlet varies.

(2) The average rate of decline of hydrocyclone with rectangular tangential inlet and flow deflector is lowest, and the decline trend of hydrocyclone with rectangular tangential inlet and flow deflector is slower than that of other hydrocyclones.

(3) Compared with Archimedes spiral inlet, the former’s manufacture technology is simpler and suitable to the rod pump’s down-hole oil-water separation system.

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