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RESEARCH ON PRESSURE COMPENSATED ACCUMULATOR

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ABSTRACT

Accumulator is the visual plant in subsea production system, As the depth of water increases, the pressure of the accumulator also increases because of the hydrostatic pressure, while its effective volume gradually decreases. The conventional accumulator no longer works when the depth of water reaches a certain level. In this paper, the structure and principle of the pressure compensated accumulator are analyzed, and its effectiveness is verified by simulation.

Key Words: accumulator; hydrostatic pressure; effective volume; pressure compensation

Introduction

The exploitation of oil nowadays has been covered from offshore to the deep sea, thus the oil in the deep will be mainly exploited by the subsea production system who seelectro-hydraulic composite control system plays a vital role in the subsea development. The accumulator which provides power for the operation of the valve actuator, is the key equipment of the electro-hydraulic composite control system in the subsea production system. With the depth of water increasing, the hydrostatic pressure become higher and higher so that the conventional structure of the accumulator is not applicable in the deep water, and the accumulator with new advanced technology is needed. Therefore, based on the influence of the hydrostatic structure on the accumulator, we aim to study the structure principle of the pressure compensated subsea accumulators.

The influence of the hydrostatic pressure on accumulators

Considering the function of an accumulator depends on whether its output fluid can start the actuator, it's fundamental to calculate the effective volume of the accumulator when designed.

The accumulator calculates its effective volume based on Boyle's law $pV=C$, and the effective volume fraction is calculated as follows:

$$VE = \frac{p_0}{p_1} - \frac{p_0}{p_2} \quad (1)$$

In the formula, $VE = (V_2 - V_1)/V_0$, p_0、 p_1、 p_2 were the pre charging pressure, the minimum working pressure and the maximum working pressure of the accumulator, V_0、 V_1、 V_2 were the gas volume in accumulator when the pressure is relative.

2.1 The influence of water depth on gas pressure in accumulator

Take an subsea production system with an output pressure of 20.7MPa as an example, subsea control module（SCM）controls a 4 "actuator, the accumulator pre charging pressure is 11.5MPa, initial volume is 10L.The simulation of the production system in different water depths is carried out by software, and the maximum pressure of the gas in the accumulator varies with the water depth:

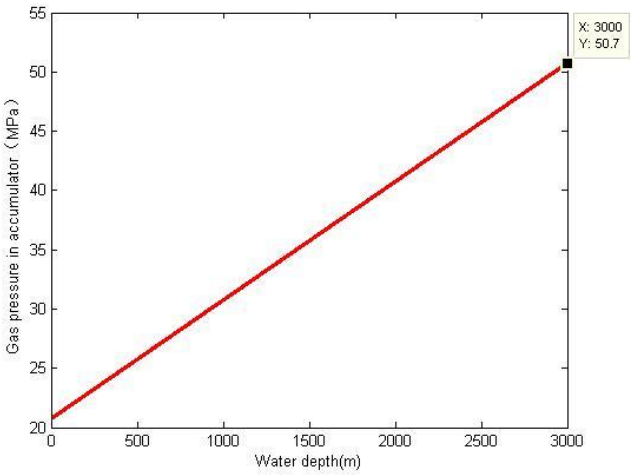


Fig. 1.Variation of maximum gas pressure with water depth in accumulator

The pressure of the gas in the accumulator is $P = P_S + 0.01h$, P_S is the system output pressure, MPa, h is water depth, m. As the water depth increases, the pressure of the gas in the accumulator increases. When the water depth is more than 1080m, the accumulator is under more pressure than the ordinary accumulator's nominal pressure 31.5MPa. At this time, the ordinary accumulator is no longer suitable, and the accumulator with higher pressure resistance is needed. In addition, the change of water depth will affect the effective volume of accumulator.

2.2 The influence of water depth on effective volume of accumulator

When the accumulator works in subsea, the calculation method of its effective volume can be divided into three kinds according to the state of the gas and the working process of the accumulator[1,2]:

（1）,The first method is that the gas in the accumulator is regarded as an ideal gas, and the operation process is regarded as a constant temperature process;

（2）,The second method is that the gas in the accumulator is regarded as the actual gas, and the operation process is regarded as a constant temperature process;

（3）,The third method is that the gas in the accumulator is regarded as the actual gas, and the operation process is regarded as an adiabatic process.

Taking the accumulator at the water surface, the pre charging pressure is 12.4MPa, the minimum operating pressure is 13.8MPa, the maximum operating pressure is 34.5MPa as an example, the effective volume fraction of the accumulator is calculated as:

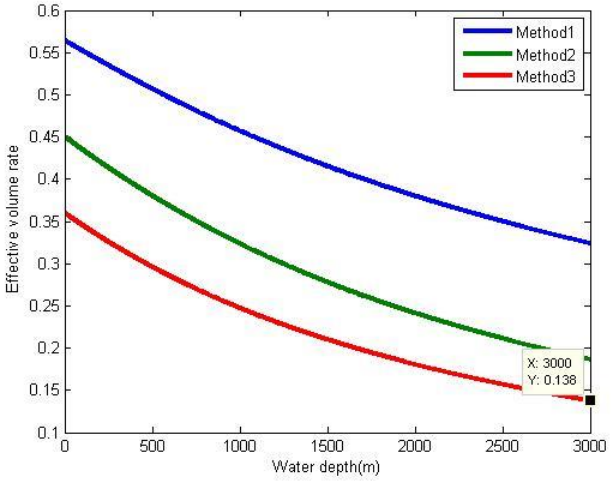


Fig.2.The relation between the effective volume fraction of accumulator and water depth

As the water depth increases, the effective volume of the accumulator decreases gradually. In the subsea production system, accumulator working time is very short, closer to the adiabatic process, the method three approach it more closely. When the depth of water is 3000m, the effective volume ratio of the accumulator calculated by method three is only 13.8%.

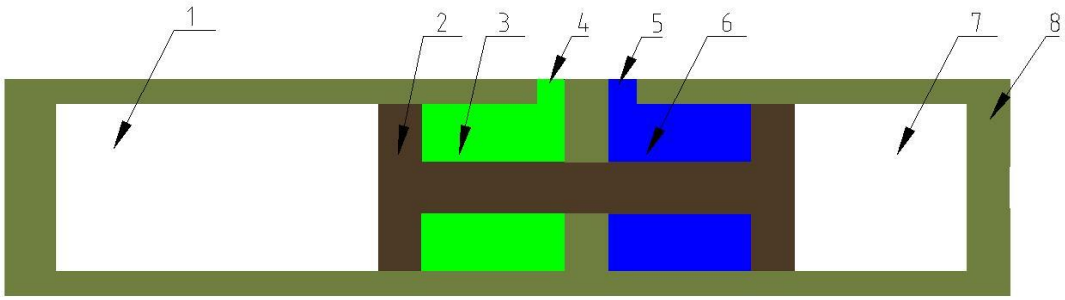
In conclusion, when the water depth more than 1080m, high pressure will make ordinary accumulator is no longer applicable; and even the high pressure accumulator, the effective volume decreases with the increase of water depth, the greater the water depth, requires larger or more number of accumulators.

Analysis of pressure compensated accumulator

In order to solve the problem of increased pressure and smaller effective volume caused by the increase of water depth, the pressure compensated accumulator compensate the hydrostatic pressure by changing the structure, so that it can eliminate the influence of the hydrostatic pressure, and it can be applied to various water depths without the influence of water depth.

3.1 Piston type pressure compensated accumulator structure

A schematic diagram of a piston type pressure compensated accumulator is shown:



1—Gas chamber 2—Piston 3—Oil chamber 4—Oil inlet 5—Seawater inlet

6—Seawater chamber 7—Vacuum chamber 8—Cylinder

Fig.3. Structure diagram of piston pressure compensated accumulator

As shown in Fig. 3, the pressure compensated accumulator is composed of four chambers: angas chamber, an oil chamber, a sea water chamber and a vacuum chamber. The volume of the oil chamber and the vacuum chamber are zero and the volume of the seawater chamber reaches the maximum when the pressure is pre charged. When the liquid is filled, the volume of the oil chamber is increased, and the piston is used to compress the gas, and the sea water chamber discharges the sea water, and a vacuum chamber is formed between the right surface of the piston and the cylinder body. When the liquid is discharged, the piston suction the sea water and discharge the oil under the vacuum chamber negative pressure and the gas pressure of the gas chamber to realize the compensation of the hydrostatic pressure.

3.2 Working principle of pressure compensated accumulator

The mechanical model of the pressure compensated accumulator piston is as shown:

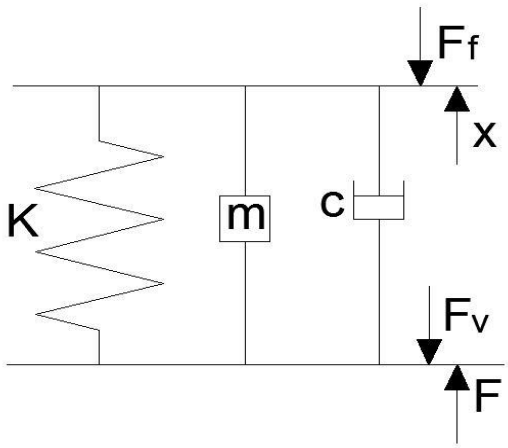


Figure.4.Piston mechanical model

The force balance equation of the piston is as follows:

$$F = m\ddot{x} + c\dot{x} + Kx + F_f + F_v \qquad (2)$$

F is the pressure of the oil on the piston, m is the piston and gas gravity, F_f is the friction, F_v is the negative pressure of vacuum chamber, K is the stiffness of gas spring, c is the equivalent viscous damping coefficient.

We can know from the model, the piston is always subjected to the downward negative pressure of the vacuum chamber, and its direction is opposite to that of the oil to the piston. The negative pressure of the vacuum chamber is equal to hydrostatic pressure because the vacuum chamber discharges the sea water and overcomes the hydrostatic pressure, that is $F_v / A = 0.1h$, A is the piston area of the vacuum chamber. The oil pressure on the piston, in addition to the relative pressure of the system, but also with hydrostatic pressure, the latter is equal to $0.1h$. The two pressure cancel each other, so the gas state in the accumulator is not affected by hydrostatic pressure, and is determined by the system output pressure.

Taking the output pressure as 20.7MPa and the subsea production system with pressure compensated accumulator as an example, the maximum pressure of the compensated accumulator varies with the water depth by simulation：

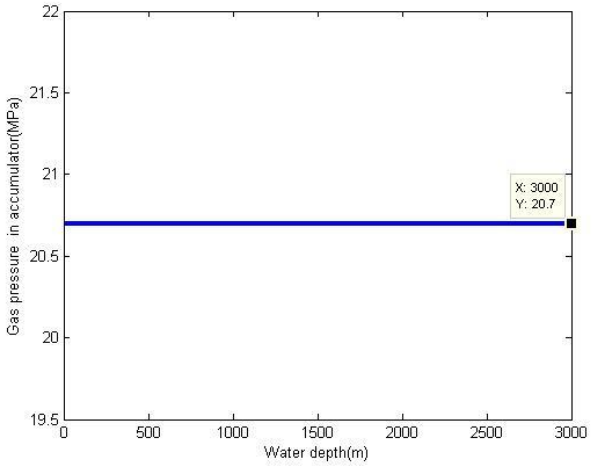


Fig.5. Change of gas pressure in pressure compensated accumulator

Ignoring the change of the ambient temperature, the maximum gas pressure in the pressure compensated accumulator is not affected by the water depth, which is equal to the system output pressure. Its maximum pressure determined by one of the greater hydrostatic pressure and system pressure, instead of the ordinary accumulator as the two together, and solves the problem that the pressure on the accumulator increases as the water depth increases.

In this case, the effective volume rate of the pressure compensated accumulator can be determined by the formula (1)：

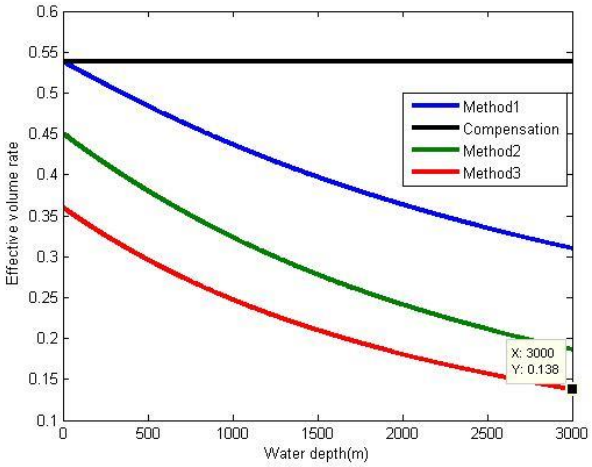


Fig.6. Relationship between effective volume of pressure compensated accumulator and water depth

Compared with ordinary accumulator, the effective volume of pressure compensated accumulator is not affected by water depth. The problem of reducing the effective volume of accumulator caused by the increase of water depth is solved, and it can be applied to different water depths.

Conclusion

With the depth of water increasing, the hydrostatic pressure also increases, which leads to the higher pressure of the accumulator and its smaller effective volume. The pressure compensated accumulator by compensating for the hydrostatic pressure, solves the problem that the pressure of accumulator increases while the effective volume decreases with the increasing of the water depth. It is an important development direction of accumulator in subsea production system in the future.

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