Using SimulationX® to realize the Challenges of Subsea Accumulators in Deep Water

Agito Doc. no.
TNO-0030 rev. 01

1. Introduction

This article describes how modern simulation tools such as SimulationX® can be applied to help realize the challenges of using accumulators in deep water BOP & IWOCS control systems.

2. Subsea Accumulators

Today's designed operating environment for stack-mounted accumulators is challenging. Design criteria include 3500 metre water depths, low subsea temperature and high surface temperatures, rapid discharge (adiabatic), as well as higher minimum system pressures. All of these things add up to a large number of bottles on a subsea BOP/IWOCS stack. It is not uncommon to see as many as 120 accumulator bottles subsea, 90+ of which are dedicated to the shear system alone. This adds weight to the overall assembly, increases maintenance requirements and decreases stack equipment access.

It is important to understand what effect the subsea operating environment has on accumulators and gas. There are three major factors that affect gas performance subsea: temperature, discharge type and water depth.

Temperature

Colder gas equals denser gas. For example, the accumulator could be precharged to its maximum working pressure at surface in high ambient temperature, with extreme exposure to sunlight.

Adiabatic Discharge

Adiabatic discharge equals rapid discharge. The definition of an "adiabatic process" is a process by which no energy is absorbed or released into the environment. When compressing a gas, that process will heat the gas. Conversely, when decompressing a gas (accumulator discharge), the gas gets colder.

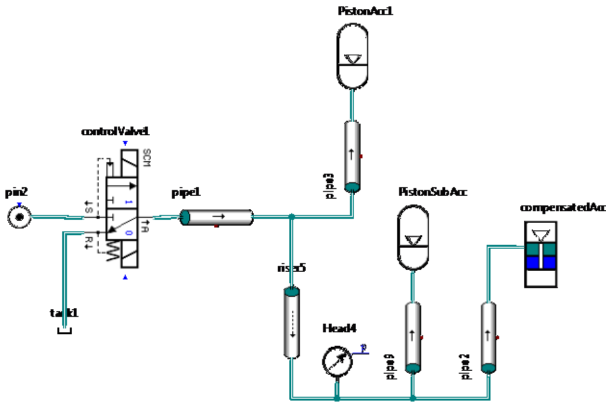
Water depth

Deeper water equals lower compression ratio. Compression Ratio is derived from the maximum system pressure (e.g. 345 bar) vs minimum pressure required to operate a function, for example 207 bar for the shear rams.

The higher the compression ratio, the springier the gas is and the better it performs. For example the compression ratio at surface would be 345/207 = 1.667. When the bottles are placed subsea, the pressure created from the water column from depth is in addition to those pressures and thus the compression ratio reduces. For example, at a depth of 2500 metres, the compression ratio subsea would be (345+264) / (207+264) = 1.29. Therefore, the gas compresses less and more volume (bottles) must be added to compensate.

3. Using SimulationX® to Verify Accumulator Efficiency

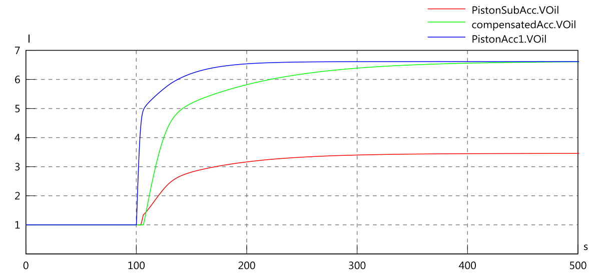
Using a simulation tool such as SimulationX®, a simple model can be produced utilizing a pressure source, DCV, umbilical, associated pipework and two accumulator types; a conventional piston type accumulator and a compensated accumulator. It should be noted that all these elements are standard features within the SimulationX® Subsea Hydraulics library. The figure below shows a screen shot of the simple system as modelled within SimulationX®.



Two N2 gassed piston type accumulators are utilized – one at surface and one subsea. A single depth compensator type accumulator is incorporated subsea. From this simple model, we can verify the characteristics of both types of accumulator, with a specific focus on the effective stored volume in each. The model presumes a system pressure of 345 bar with a sea depth of 2500 metres. The sea pressure at this depth is calculated at approximately 264 bar.

Both the surface mounted piston accumulator and the compensated accumulator have pre-charge pressures of 142 Bar. The Piston accumulator modeled subsea has a pre-charge of 406 bar (142+264).

The model simulates a simple system charge up case. At t=100 seconds, the DCV is switched to allow the 345 bar system pressure into the circuit. Fluid will migrate to the surface piston accumulator via a short pipe, and to the subsea piston and compensated accumulators via an umbilical and 2 short lengths of pipe. The following graph shows the effective fluid volumes all three accumulators once pressure and flow has stabilized.

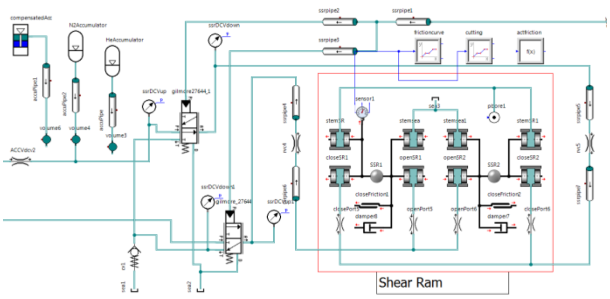


The graph verifies the results showing all 3 accumulators have a dead volume of 1 litre. At t=100 seconds, the blue trace shows the surface piston accumulator volume stabilize first with an effective fluid volume of 5.61 litres. Eventually, the subsea piston and compensated accumulator volumes stabilize. As we can clearly see from the results, the subsea piston accumulator stabilizes at an effective fluid volume of 2.45 litres, and the subsea compensated accumulator stabilizes at an effective fluid volume of 5.61 litres, confirming that the performance is not affected by subsea deployment.

4. Using SimulationX® to Verify a BOP Shear Ram Operation

Now that we understand the effects of each accumulation type, we can incorporate them into a physical model. The diagram below shows a typical SimulationX model of a Shear Ram with associated pipework. Three accumulation alternatives are considered:

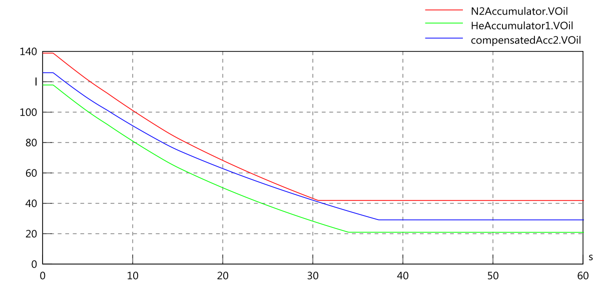
1) Standard Piston Accumulator with N2 Gas
2) Standard Piston Accumulator with He Gas
3) Compensated Accumulator with N2 Gas



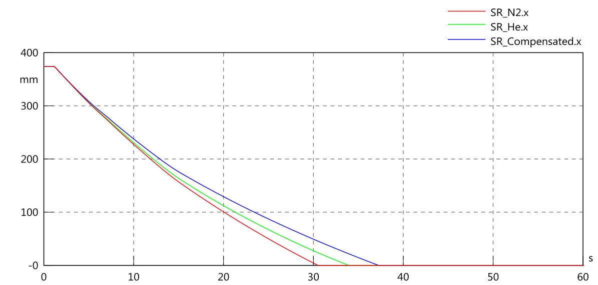
A simulated *'close'* sequence is executed for the shear ram, powered only by each type of subsea accumulation. No topside assistance is considered. Fundamentally, the accumulator capacity for each variant is calculated for the required fluid volume and sea depth in accordance with the requirements of API16D. The results of which are as follows;

Accumulator	Calc. method Ref. API-16D	Bottles x volume	Gas pre-charge
Std Acc – Nitrogen fill	C	13 x 50 litre	388 barg @ 20°C
Std Acc – Helium fill	C	9 x 50 litre	360 barg @ 20°C
Compensated	C	5 x 50 litre	135 barg @ 20°C

The accumulator bottle volumes and gas precharge are considered in each model. The results of which are shown graphically below;



The graph above shows the stored volume characteristics during valve closure.



The graph above shows the actuator stroke position against time during the closing operation. The performance difference between the 3 alternatives is largely due to the dynamic effects of the accumulator during the operation.

5. Conclusion

The loss of effective fluid volume in deep water means the need for more accumulators and higher working pressures, all leading to extra cost and perhaps more importantly, more space and mass to be deployed subsea. By using a tool such as SimulationX®, many potential design solutions can be explored well in advance to ensure optimised performance and economic targets are achieved. Again, SimulationX® provides a means of visualizing the solution and removing the risk.

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