Pressure Cycling of Dive Chambers

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We have been working with 4Subsea and DNV on pressure cycling of dive chambers, with the same goal – avoiding hydro testing and reducing overpressure testing gas to extend the life of the chambers.

Specific acknowledgements for work carried out to should go to:
Matthew Watson at Subsea7
Arnfinn Hansen at DNV
Hedda Sofie Sjøvaag at 4Subsea
Why do we test?

It’s the rules - We have to test our pressure vessels (PVHO).

The very testing that we were carrying out was likely to be reducing the life of the chambers.
The Options

- Hydraulic Overpressure test
  This brings lots of challenges, not least stripping out time (and subsequent rebuild) of the chamber and a lot of weight being added during the actual test.
- Gas leak testing at MAWP and Eddy Current (ET) Testing to be carried out on the outside part of some pre-defined welds.
1.3.1 Chamber and bells For systems having digital pressure monitoring with a record of the actual cycles experienced, testing shall be invoked when 20% of the design fatigue life have been reached for the worst-case chamber. For systems not able to provide documentation of the pressure cycling since new, testing shall be invoked at a 10-year cycling basis.
The Solution

- Use the data that we have.
- After all, how hard can it be? We already have the sensors, and the saved data.
The data.

- Seven Falcon is fully NORSOK compliant so there is a lot of data stored.
- We narrowed down the sensors to pressure and temperature.
- One day produces over 118000 outputs. This was a normal diving day!
4insight® Data Analytics

- Data Analytics.
- This is really where the project started to come together.

- DNV gave us options, we knew what we wanted, but didn’t really know how to get there.
- Enter 4Subsea. 4Subsea is a company in the Subsea 7 Group.
- And data is what they do!

- It’s not just as simple a drop the numbers into a chart.
Rainflow Counting

- When counting part cycles, the rainflow-counting technique in accordance with ASTM E1049-85 Standard Practice for Cycle Counting in Fatigue Analysis, shall be used.
The Rainflow counting method

1. Reduce the time history to a sequence of peaks and valleys.

2. Count number of half-cycles. Each half-cycle starts at a peak/valley and is terminated when either
   - It reaches the end of the time-series
   - It merges with a flow starting at an earlier peak/valley
   - It meets a peak/valley which is larger/smaller or equal to the peak/valley the cycle originated from

3. Assign a magnitude to each cycle by calculating the pressure difference between its start and termination.

4. Organize half-cycles in bins of different pressure-range.

5. Use the pressure-range distribution to calculate total damage, as seen in "Damage calculation"
Example

1. Counting half-cycles originating from valleys (red marker):
   - A-D: half-cycle terminates at (E). (E) is of the same magnitude as (A).
   - C-B: half-cycle terminates as it merges with a flow starting at an earlier valley (A-D).
   - E-F: half-cycle terminates at (G). (G) is of the same magnitude as (E).

2. Counting originating from peaks (green marker):
   - B-C: half-cycle terminates at (D). (D) is of the larger magnitude as (B).
   - D-E: half-cycle terminates as it reaches the end of the time-series.
   - F-G: half-cycle terminates as it merges with a flow starting at an earlier peak (D-E).
Calculation of damage

• In order to calculate the accumulated material damage caused by the part cycles, the following equation shall be used:

\[
\text{Fatigue Damage} = \sum_{\text{Pressure range}} \left( \frac{\text{Pressure range}}{\text{MAWP}} \right)^m \frac{\text{Number of cycles}}{C}
\]

Where;
Pressure range is the maximum pressure for the part cycle
MAWP = Maximum Allowable Working Pressure
\( m = 1 \)
\( C = Number \ of \ fatigue \ cycles \ used \ for \ design \)
<table>
<thead>
<tr>
<th>Chamber</th>
<th>Pressure Cycle Utilization (20% allowable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDC1</td>
<td>14.99 %</td>
</tr>
<tr>
<td>SDC2</td>
<td>13.96 %</td>
</tr>
<tr>
<td>DDC4</td>
<td>1.51 %</td>
</tr>
<tr>
<td>DDC1</td>
<td>1.48 %</td>
</tr>
<tr>
<td>DDC3</td>
<td>1.24 %</td>
</tr>
<tr>
<td>DDC2</td>
<td>1.14 %</td>
</tr>
<tr>
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</tr>
<tr>
<td>DTC1</td>
<td>0.74 %</td>
</tr>
<tr>
<td>DDC5</td>
<td>0.71 %</td>
</tr>
<tr>
<td>DDC8</td>
<td>0.64 %</td>
</tr>
<tr>
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<td>0.57 %</td>
</tr>
<tr>
<td>DDC7</td>
<td>0.51 %</td>
</tr>
<tr>
<td>EscapeTrunk PS</td>
<td>0.39 %</td>
</tr>
<tr>
<td>EscapeTrunk SB</td>
<td>0.36 %</td>
</tr>
</tbody>
</table>

Pressure cycle range (msw)

5  419
Conclusions

- We are able to accurately demonstrate the pressure cycles of our chambers.
- The vast majority are not even close to their 20% fatigue life ‘test’ point.

- This reduces testing – which we know can increase fatigue -ultimately increasing the life of the chambers.
- This reduces the need to use scarce resources, eg helium.
- It reduces personnel risk.
- It reduces equipment downtime.
- We can target specific testing to higher fatigue areas (specific welds).
THANK YOU