# Delmar Systems

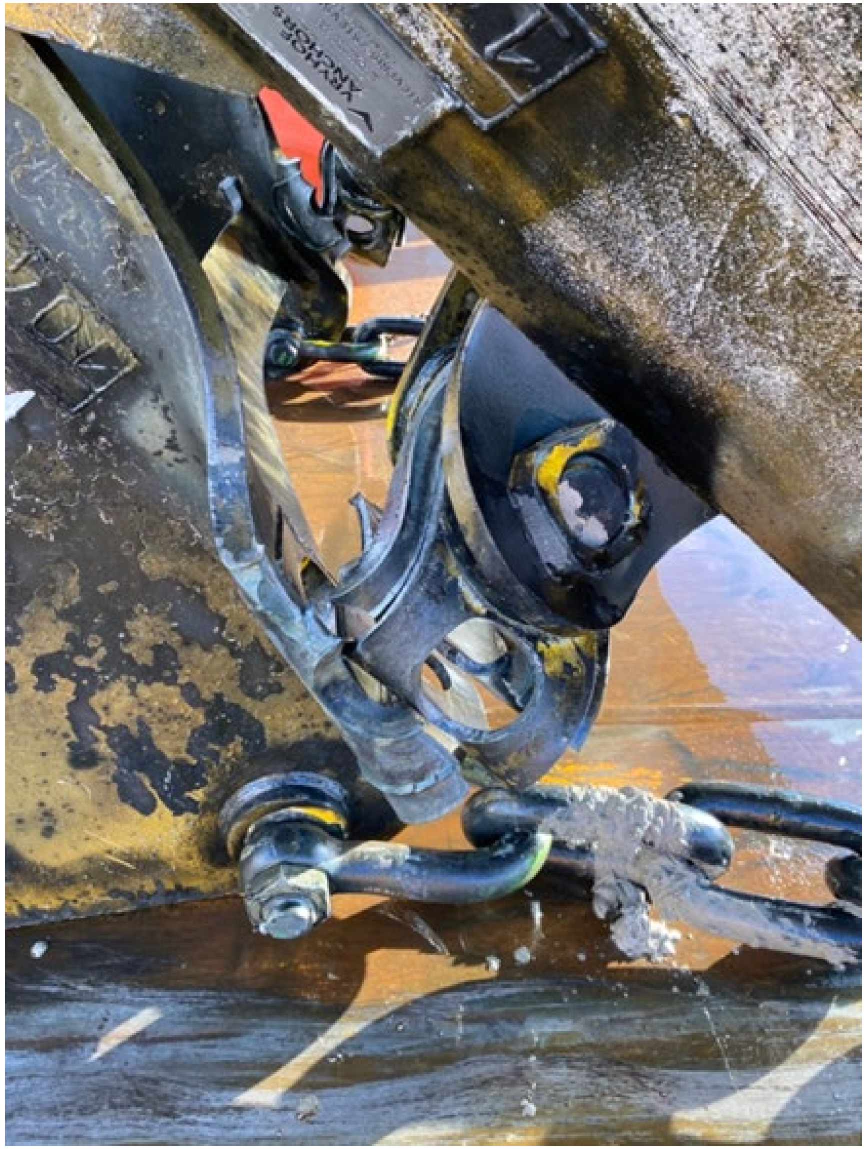
# Anchor Retrieval

# Equipment damage

Anchor handling in general is a fairly rough pastime. The attrition rate on mooring equipment [and vessels] is high compared to other sectors of the offshore industry.

A few years ago in the DSM/Vryhof Group [as it was at the time], it became clear that most of the high-impact damage we were experiencing occurred at the anchor recovery phase of the operation.

# Buckling at angle adjustment lugs



# Response

"We must determine what happened and ~~who's to blame~~ how to prevent it happening again."

# Causes

**Two possible / probable causes:**

AHV turns 180° and accelerates [winch brake on] – excessive load spike when chain comes tight.

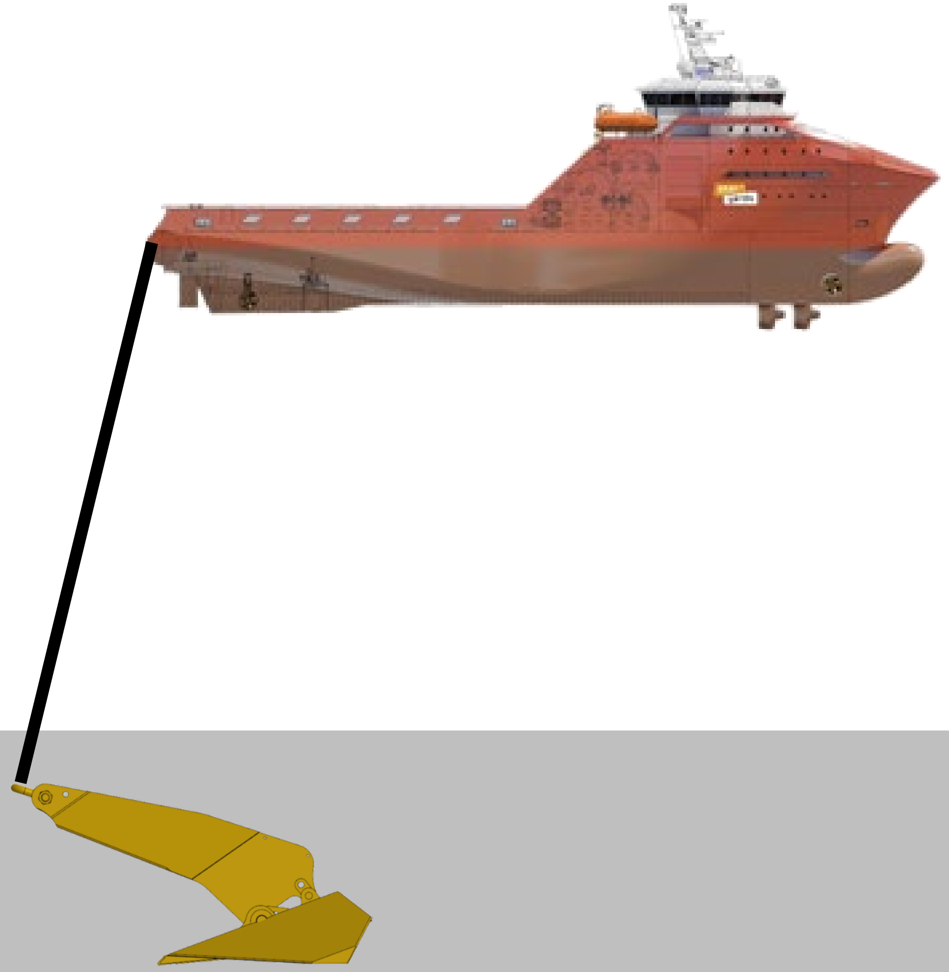
AHV turns 180° and attempts to break out [winch brake on] with an excessively short line.

# AHV heave / pitch – short line / no sag

When the stern roller rises [due to pitch, heave, or a combination], a line close to up-and-down has no scope to absorb this motion.

These forces have to go somewhere! If we're lucky, the anchor breaks out of the mud without damage.

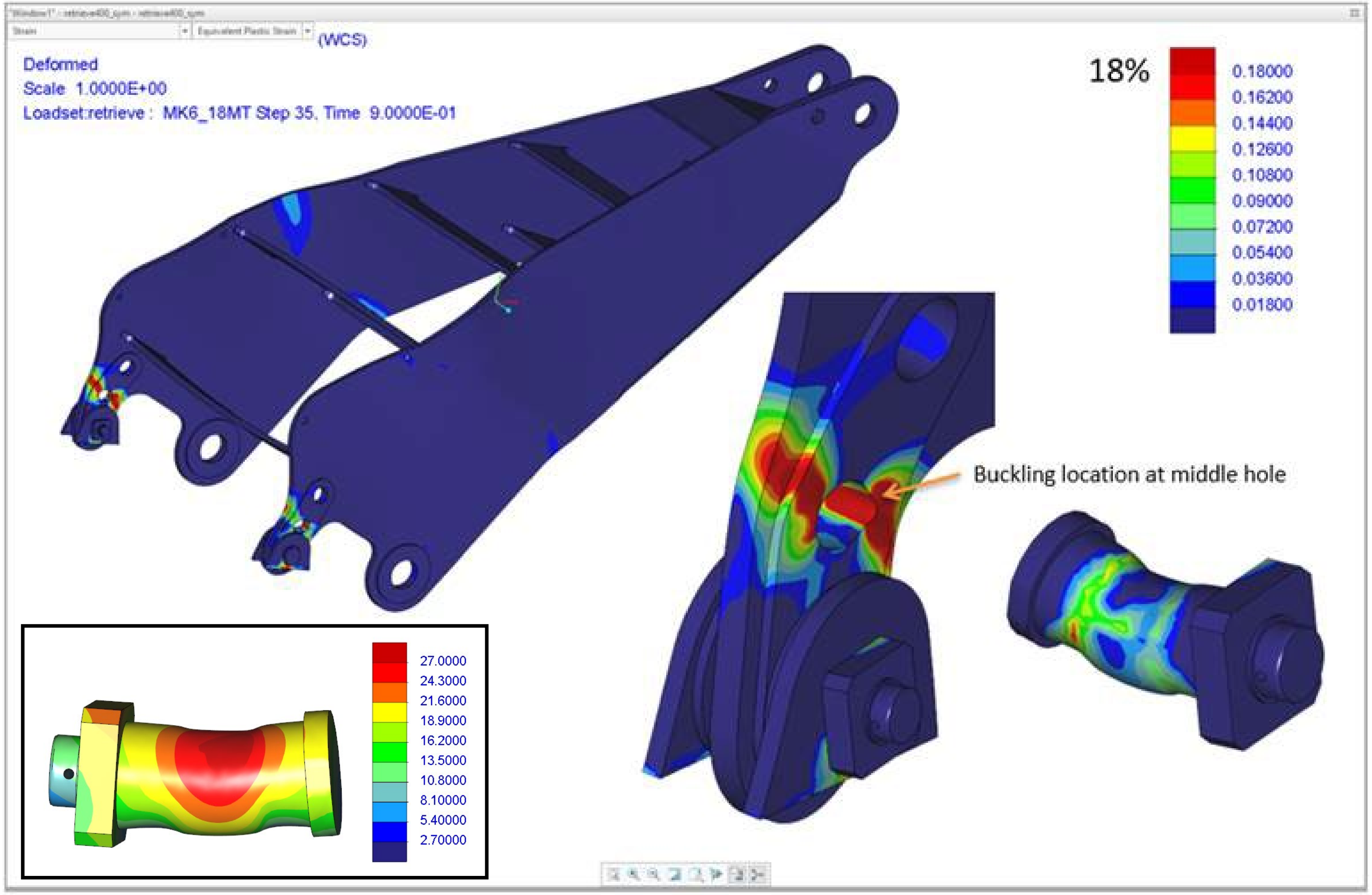
**<u>However:</u> when such sudden, snatching forces are applied to a component, fatigue life is eaten up even if the cosmetic damage is minimal.**



# Overload

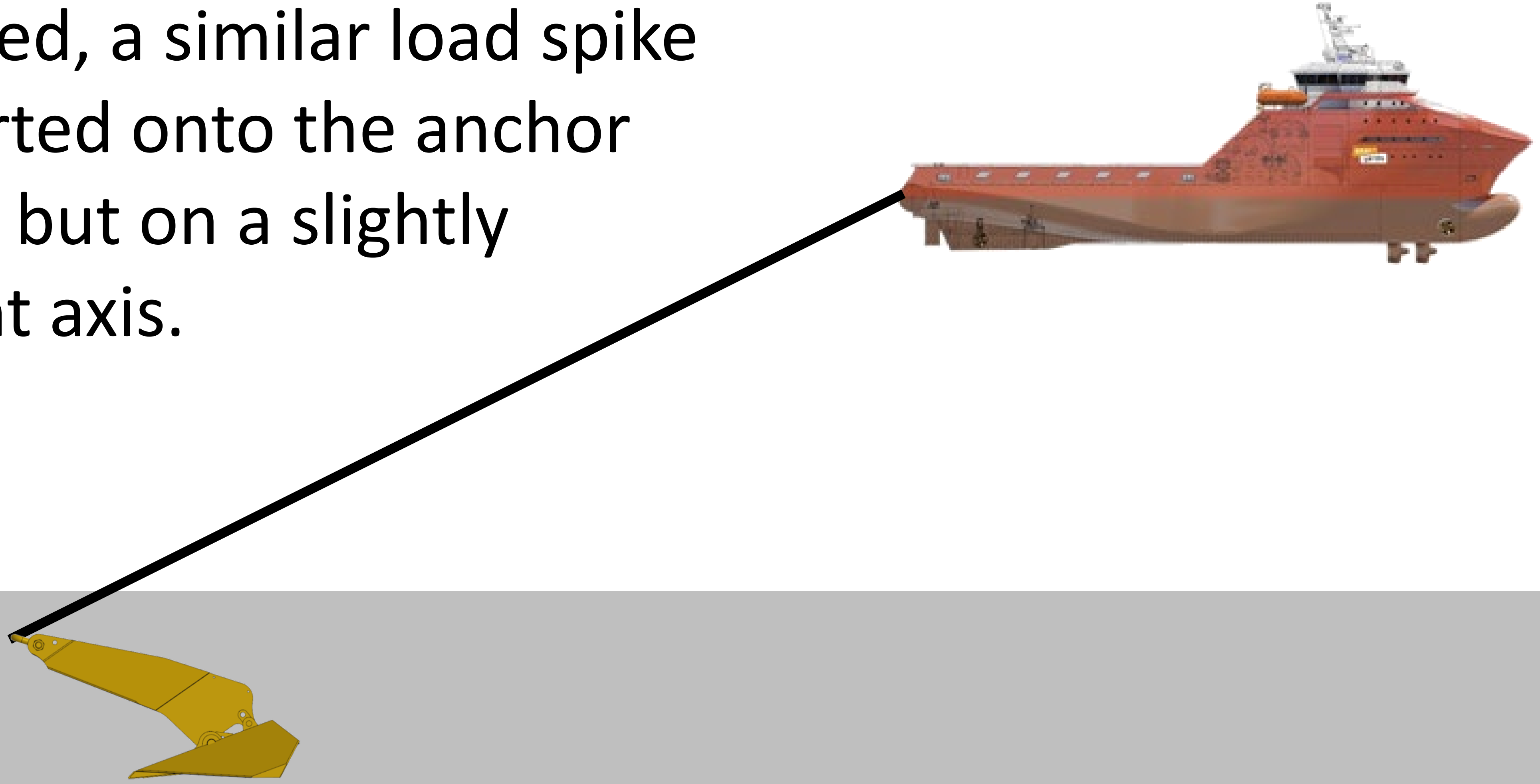
In this case a retrieval force of approx. 360Te was applied perpendicular to the shank.

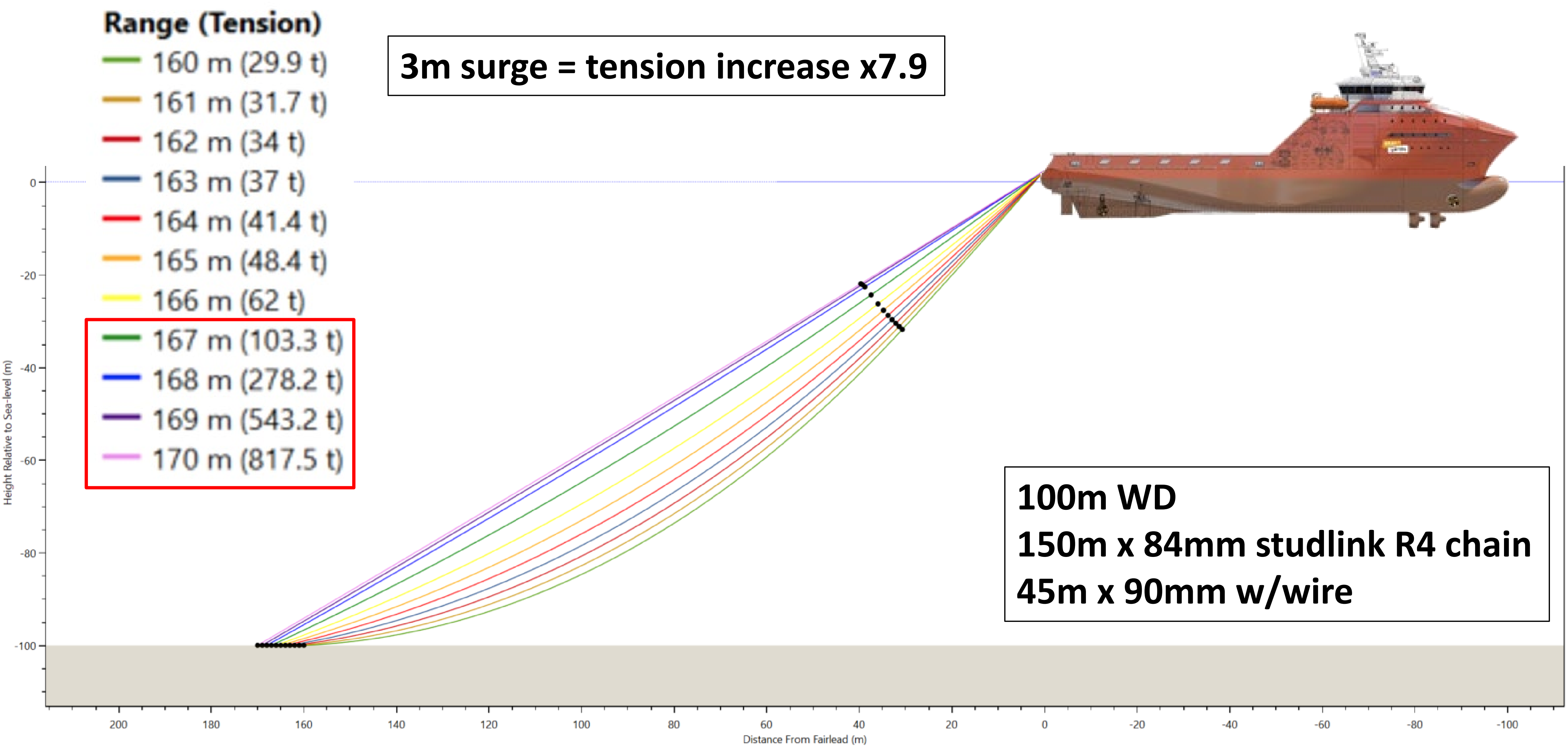
Equivalent plastic strain



# AHV surge / yaw – long line / no sag

When surge and yaw are combined, a similar load spike is imparted onto the anchor system, but on a slightly different axis.




Range (Tension)
160 m (29.9 t)
161 m (31.7 t)
162 m (34 t)
163 m (37 t)
164 m (41.4 t)
165 m (48.4 t)
166 m (62 t)
167 m (103.3 t)
168 m (278.2 t)
169 m (543.2 t)
170 m (817.5 t)
3m surge = tension increase x7.9
100m WD
150m x 84mm studlink R4 chain
45m x 90mm w/wire
Height Relative to Sea-level (m)
Distance From Fairlead (m)
0
-20
-40
-60
-80
-100
200
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100

# Combined effect

The corkscrew motion is familiar to anyone who's spent any time on boats – simultaneous motion on all six axes.

Even if the movement on each of those axes is small, the combined effect can impart enormous loads on a mooring line.

# Response

We started producing location-specific anchor recovery procedures.

Initially we looked at pulling the anchors out via a lay down pennant connected to the bridle, but this proved to be a dreadful idea:


The retrieval forces show a peak value of 100-110% of the installation force.

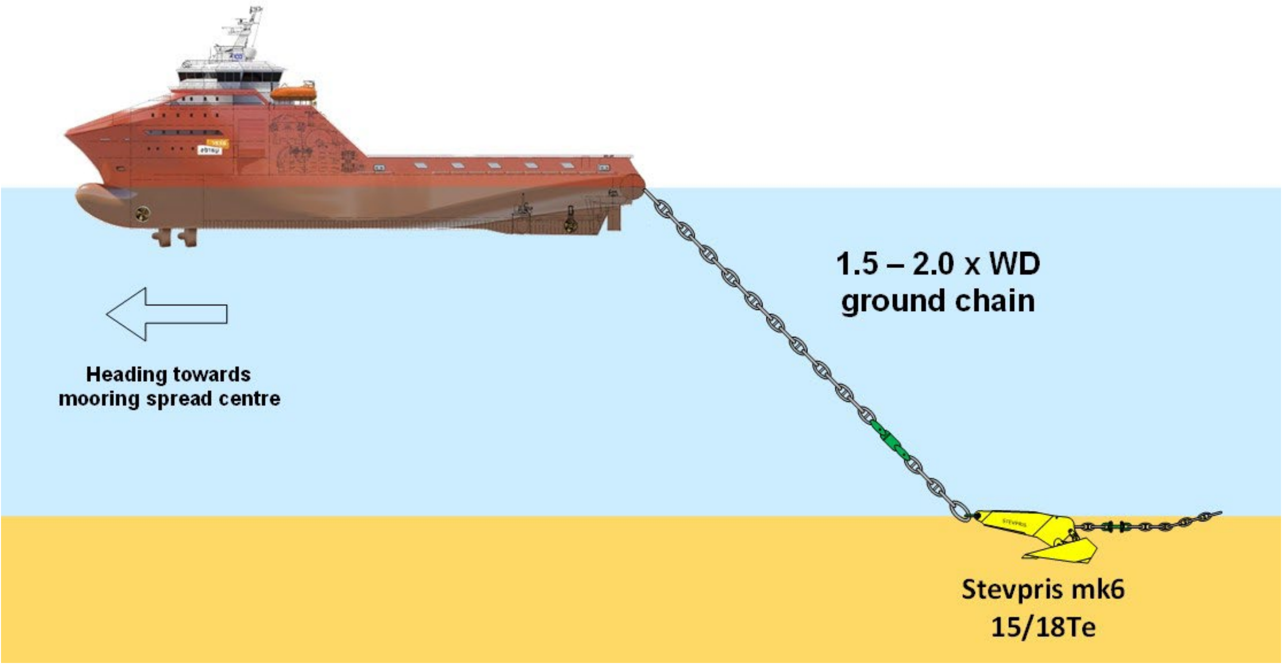
This load is required for a longer period than breaking out via the anchor chain.

There is also an issue with the inward buckling of the shank connection points – reduced by fluke lugs [REX + mk7].

# Response

Most locations in the UK sector of the North Sea are best suited to mk6 or REX anchors set at the SAND angle.

With this in mind, we focused on pulling them out forwards with 1.5 - 2x WD line length.



# Reasoning

We believed that a major factor in the damages we were seeing was the line hanging slack as the AHV direction was changed 180°, causing a shock load as tension was re-applied.

# Pros + cons of pulling out forwards

**Pros**

- No need for line to hang slack at any point.
- Reduce strain on angle lugs due to application of force away from the area.

**Cons**

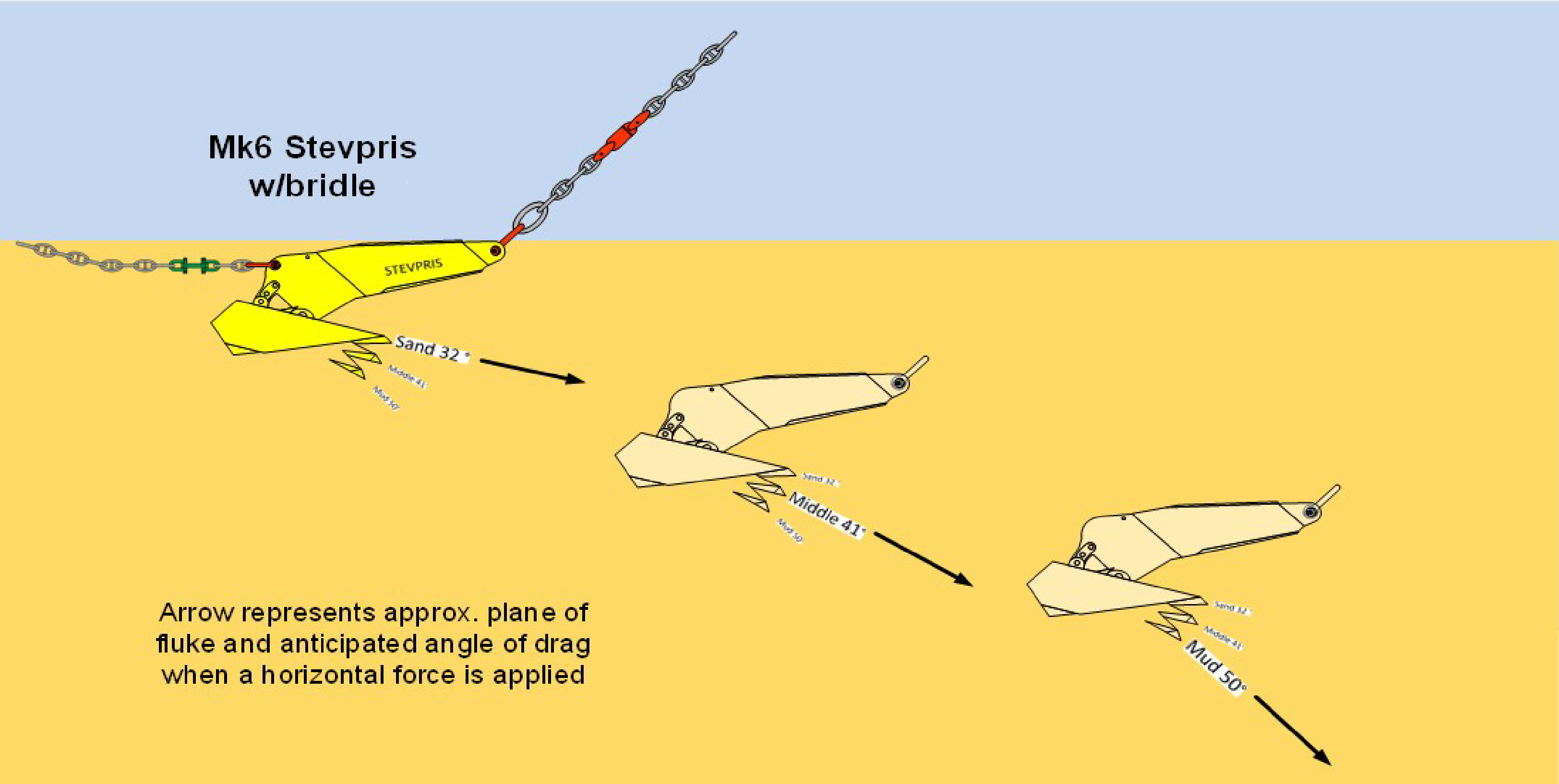
- High tensions required.
- Not suitable for MIDDLE or MUD angles.

# Pulling forwards

An anchor set to the MIDDLE or MUD angle cannot be broken out forwards. The line would have to be excessively shortened to impart an uplift; this would create an excessively stiff system [especially in shallow water].

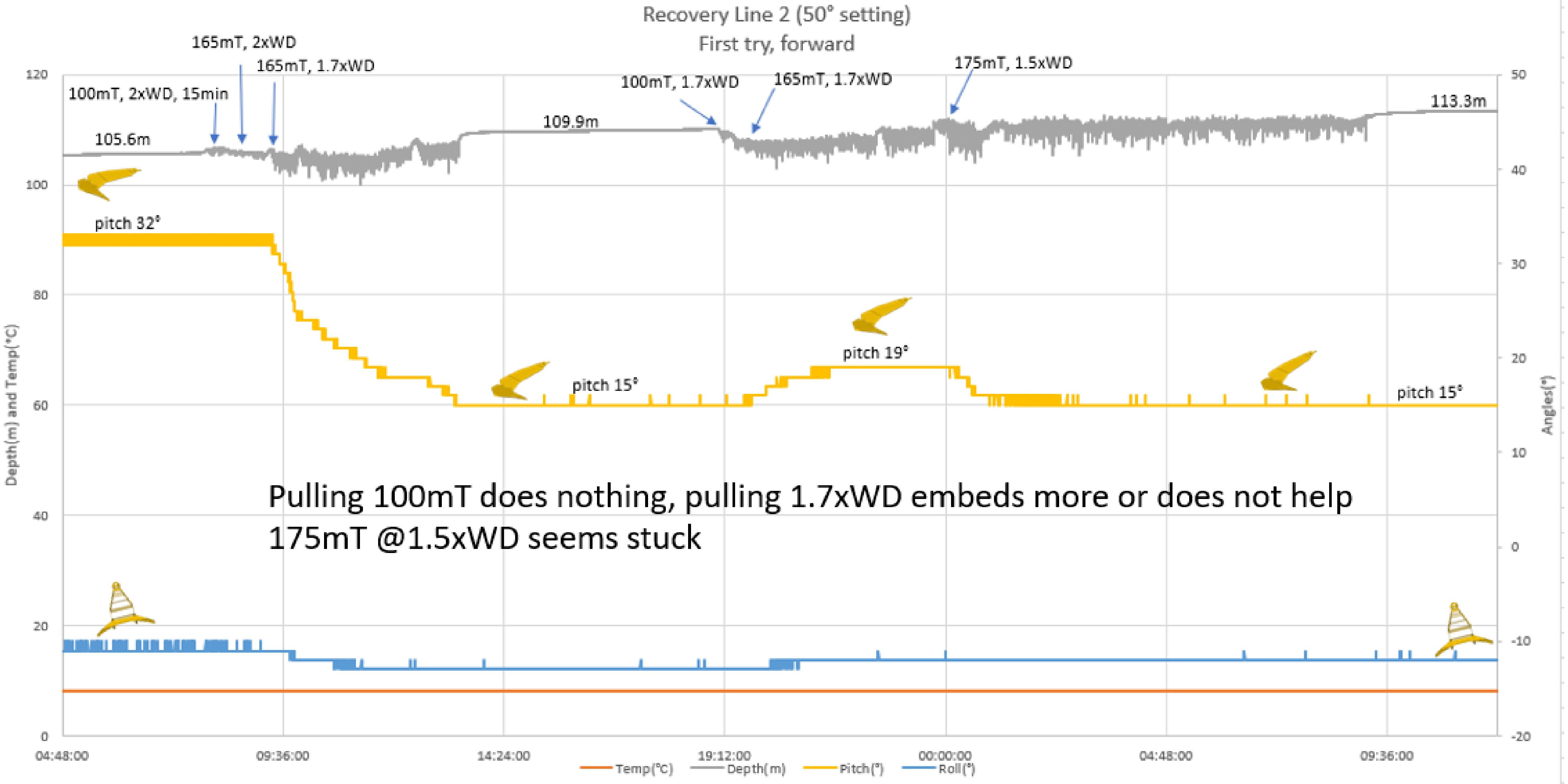
With a longer line, the anchor is likely to embed further.

**However, when circumstances were appropriate, this method initially worked well.**



# Pulling forwards [MUD ANGLE] – example from a few years ago

## Approx. 100m WD / fluke angle 50° / pulling forwards

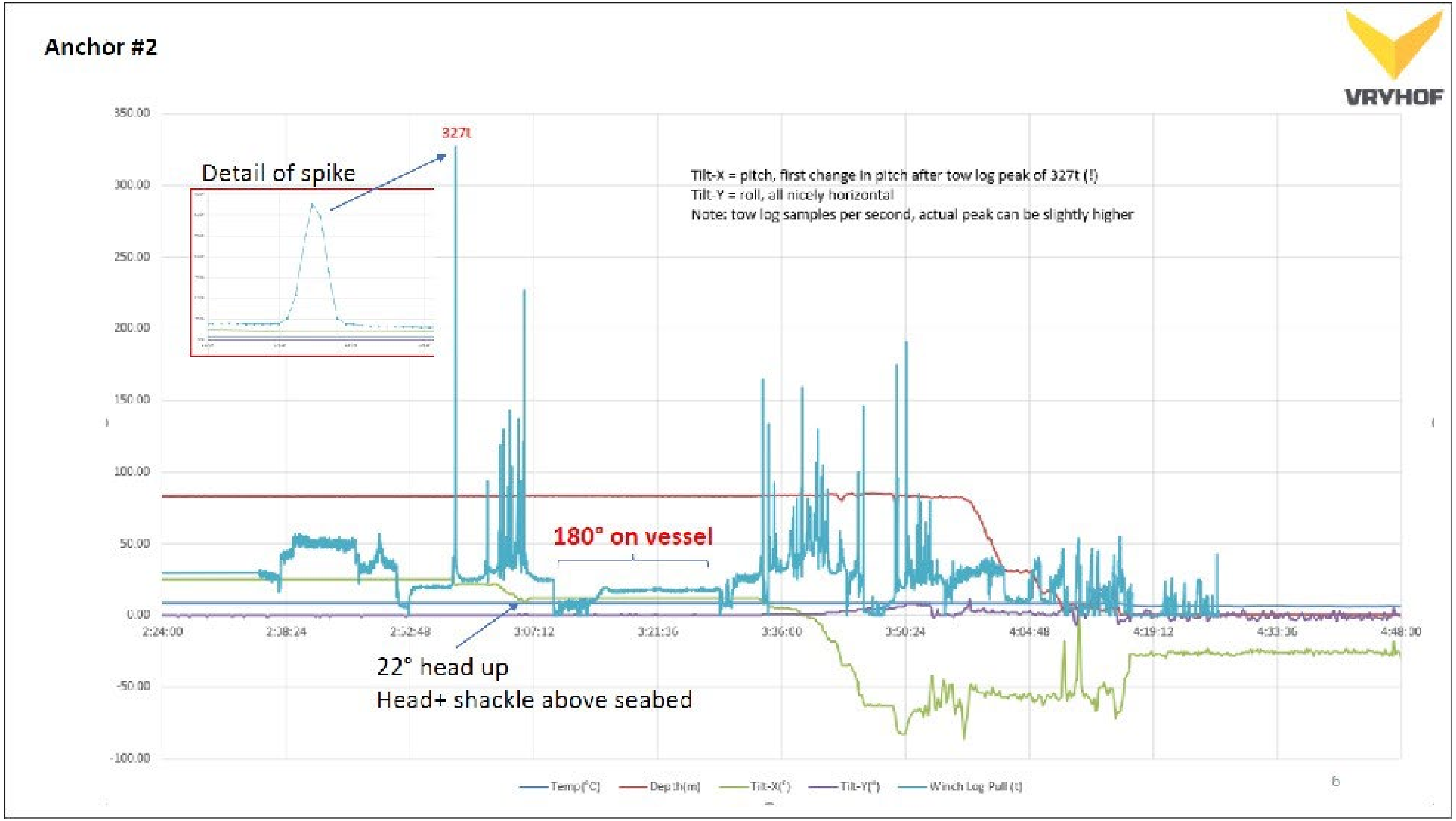


# This worked … until it didn't

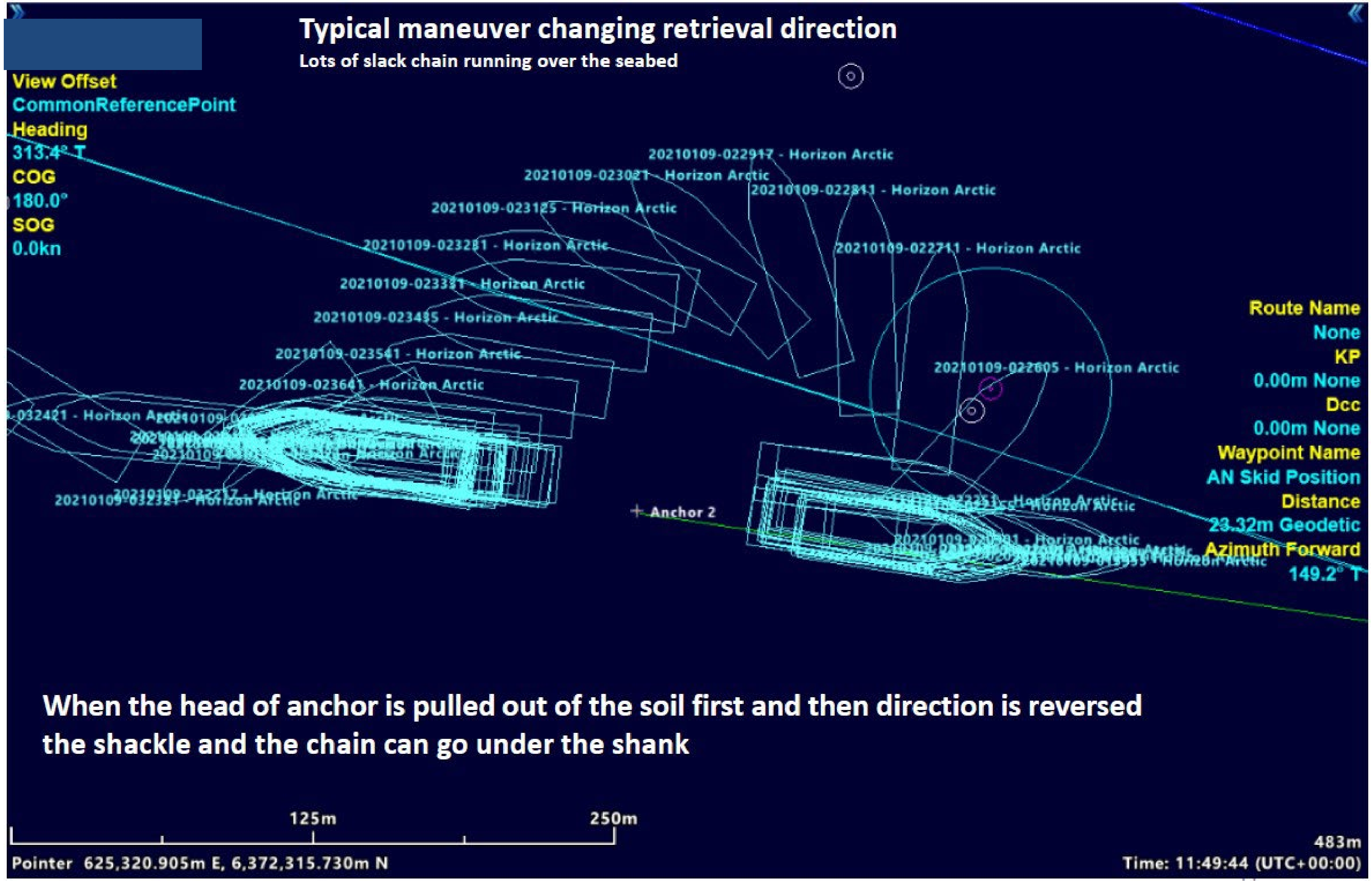

This anchor costs approx. £100k at current market prices; the knock-on effect on critical path operations is impossible to quantify.

By chance, we had a sensor fitted to this anchor, so we have a clear picture of what happened – **a freak occurrence exposed a weakness in our advice.**

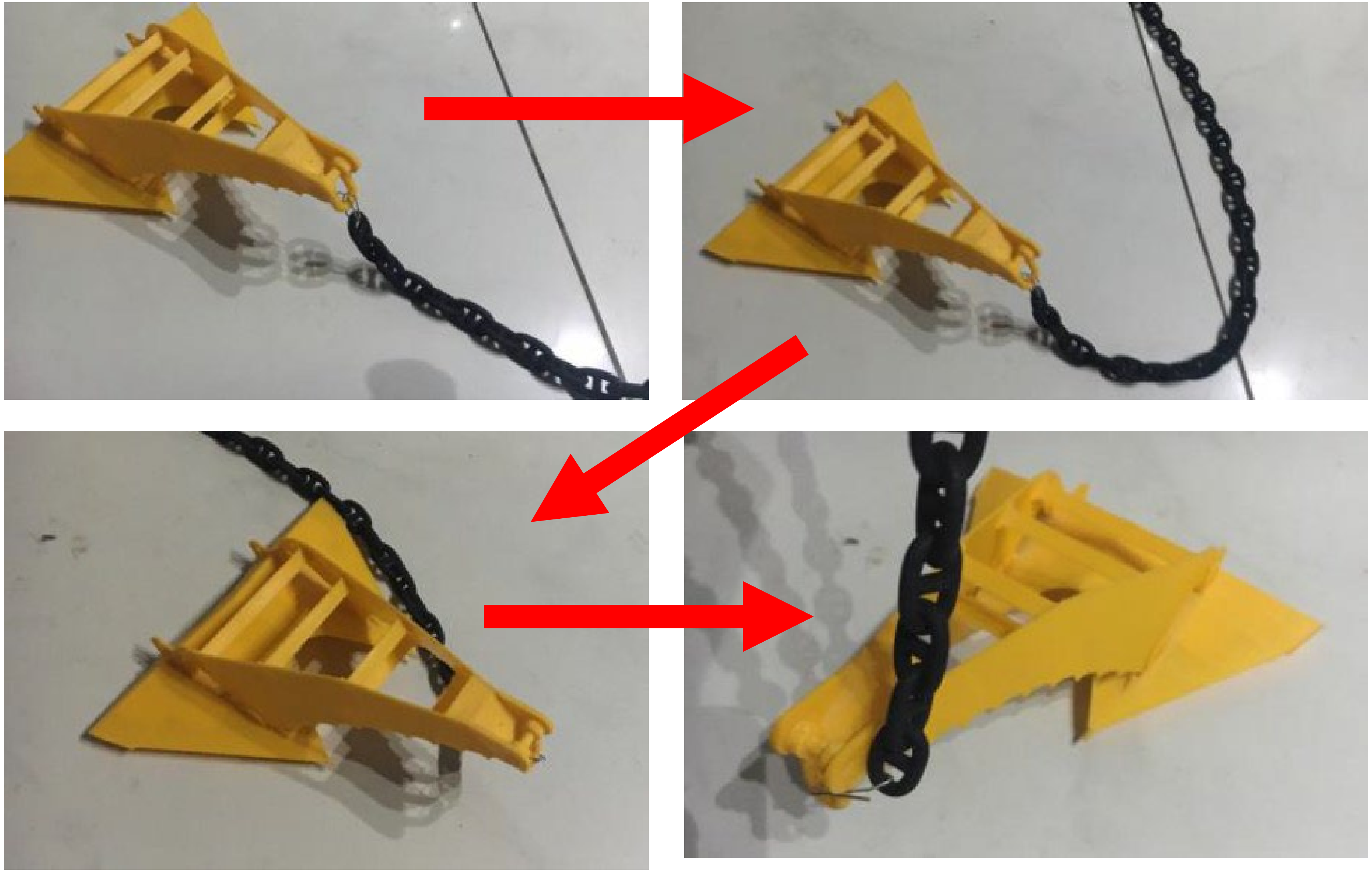
# Analysis



Anchor #2
VRYHOF
327t
Detail of spike
Tilt-X = pitch, first change in pitch after tow log peak of 327t (!)
Tilt-Y = roll, all nicely horizontal
Note: tow log samples per second, actual peak can be slightly higher
180° on vessel
22° head up
Head+ shackle above seabed
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
2:24:00
2:38:24
2:52:48
3:07:12
3:21:36
3:36:00
3:50:24
4:04:48
4:19:12
4:33:36
4:48:00
Temp(°C)
Depth(m)
Tilt-X(°)
Tilt-Y(°)
Winch Log Pull (t)


Typical maneuver changing retrieval direction
Lots of slack chain running over the seabed
View Offset
CommonReferencePoint
Heading
313.4° T
COG
180.0°
SOG
0.0kn
20210109-022917 - Horizon Arctic
20210109-023021 - Horizon Arctic
20210109-022811 - Horizon Arctic
20210109-023125 - Horizon Arctic
20210109-023231 - Horizon Arctic
20210109-022711 - Horizon Arctic
20210109-023331 - Horizon Arctic
20210109-023435 - Horizon Arctic
20210109-023541 - Horizon Arctic
20210109-022605 - Horizon Arctic
20210109-023641 - Horizon Arctic
20210109-022217 - Horizon Arctic
Anchor 2
Route Name
None
KP
0.00m None
Dcc
0.00m None
Waypoint Name
AN Skid Position
Distance
23.32m Geodetic
Azimuth Forward
149.2° T
When the head of anchor is pulled out of the soil first and then direction is reversed the shackle and the chain can go under the shank
125m
250m
483m
Pointer 625,320.905m E, 6,372,315.730m N
Time: 11:49:44 (UTC+00:00)

# Amazingly, this happened twice!



# Time to mobilise the nerds …

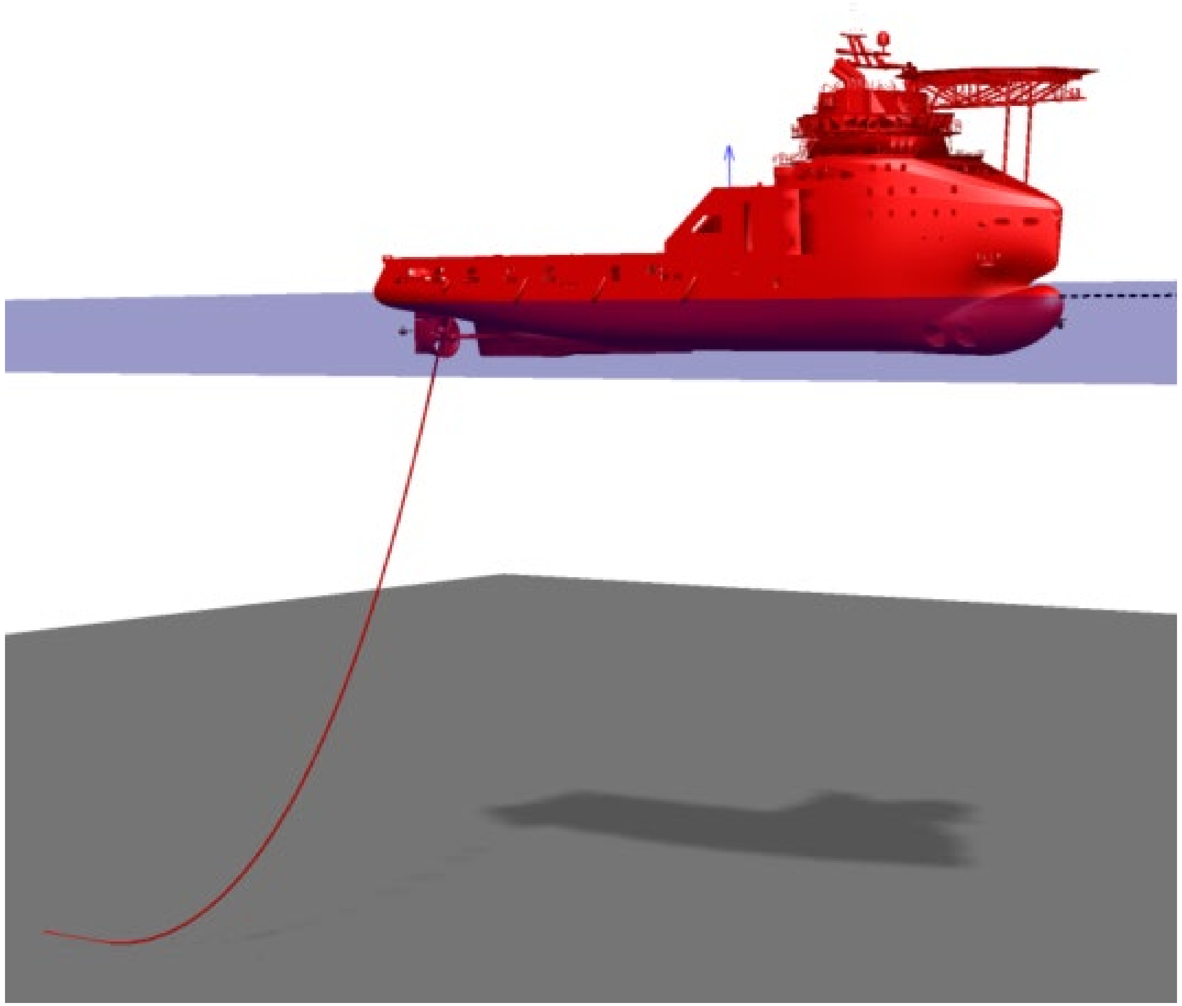
# Retrieval tests in the Rotterdam sandpit

# Analysis model – Kai Roger Nilson

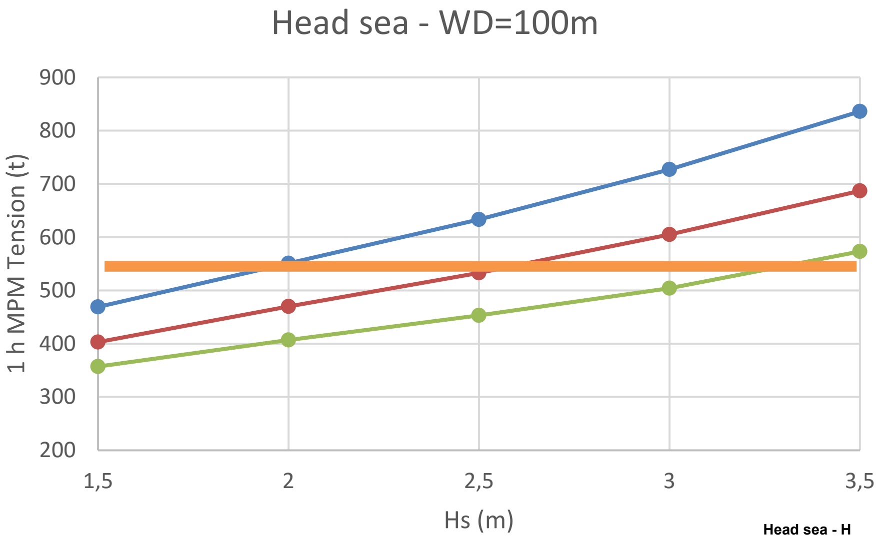
- Skandi Skansen – X-large AHV

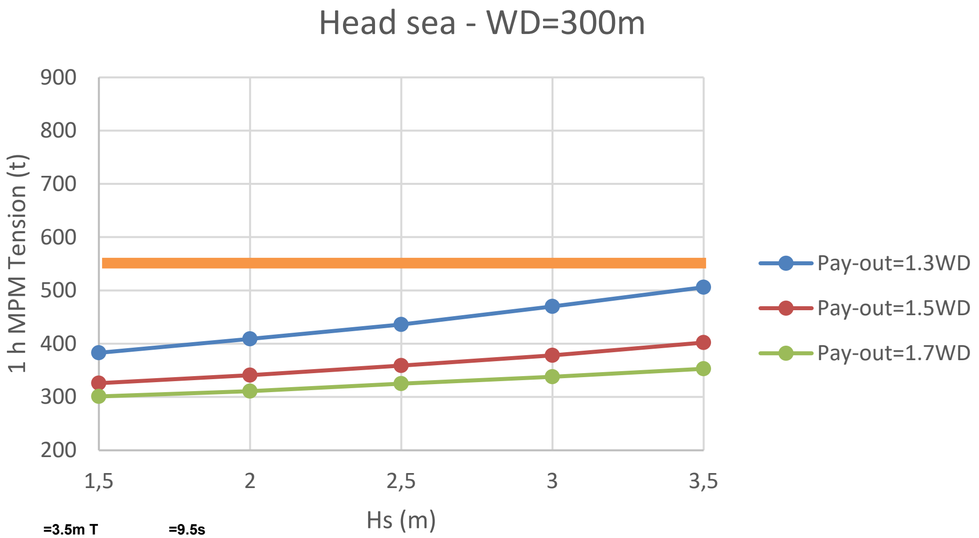
  LxBxT = 110m x 24m x 7m

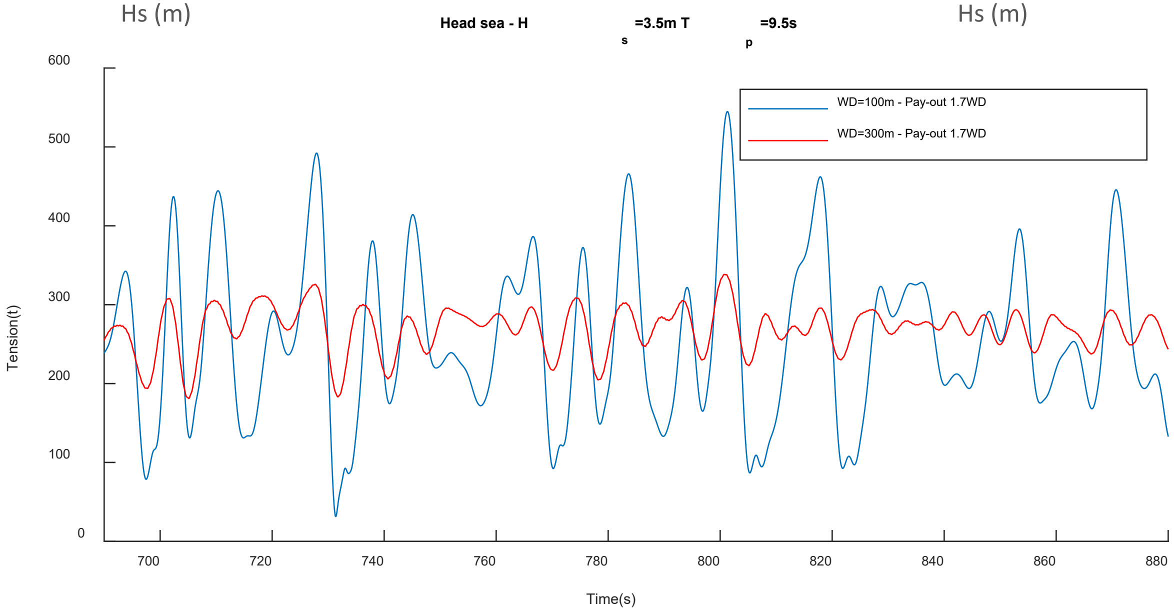
  $\Delta$ = 12500t
- System modelled in SIMO and RIFLEX
- Heading control



# Effect of water depth and pay-out



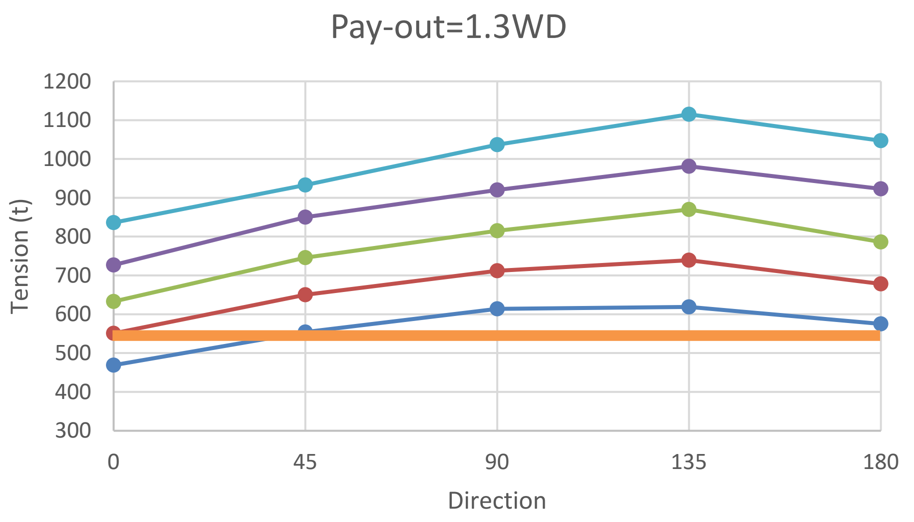



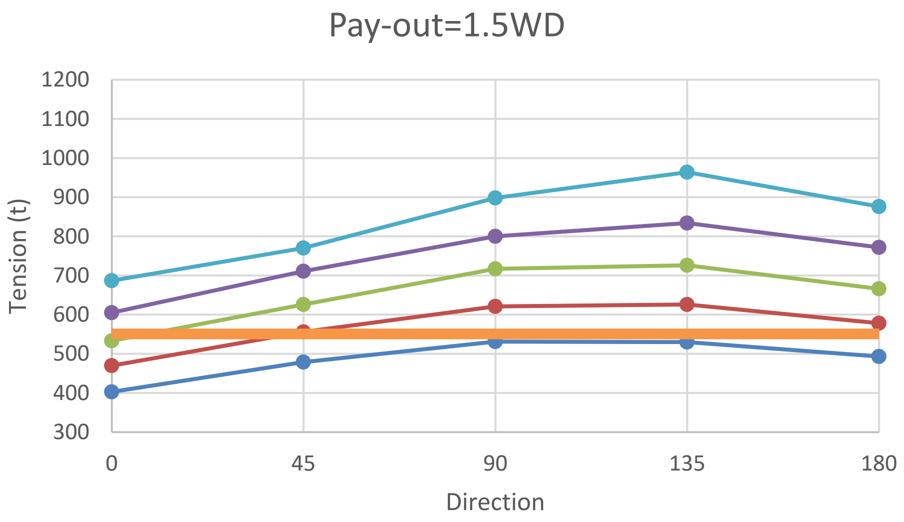




Tension levels corresponds to MPM [most probable maximum] during 1 hour.

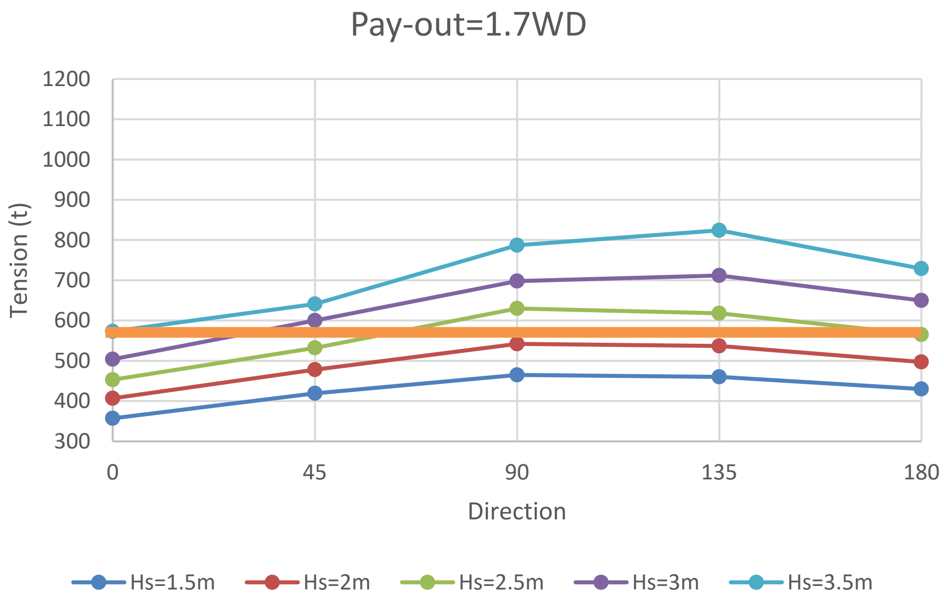
Indicate 65% of MBL

# Directional results – 100m WD



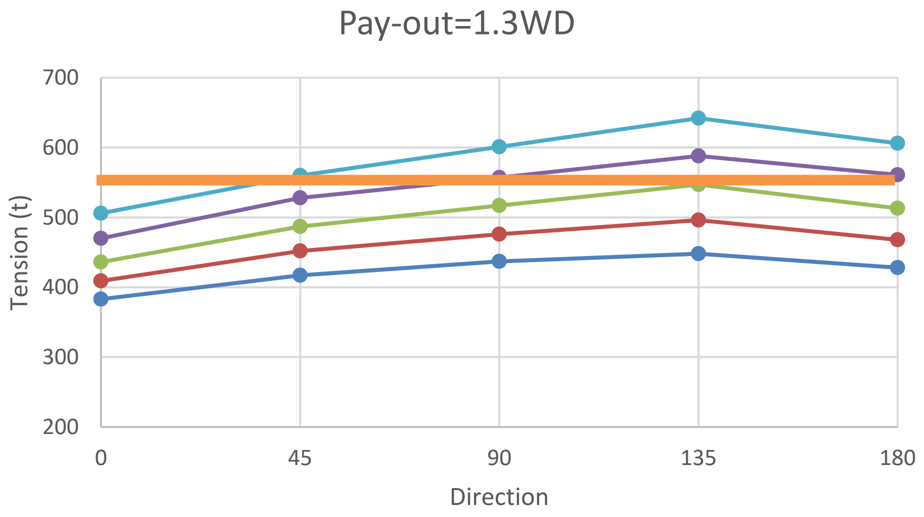



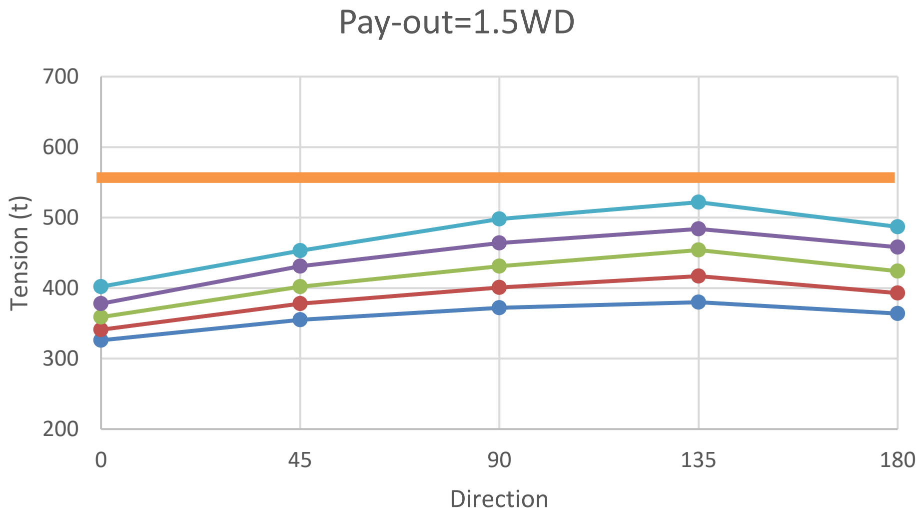

0° is from stern

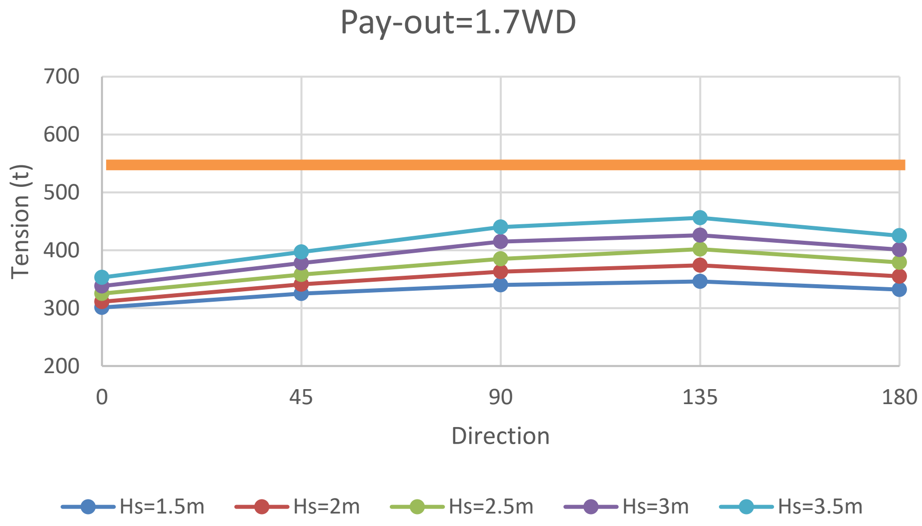



Tension levels corresponds to MPM over 1 hour. ▬ Indicate 65% of MBL

# Directional results – 300m WD



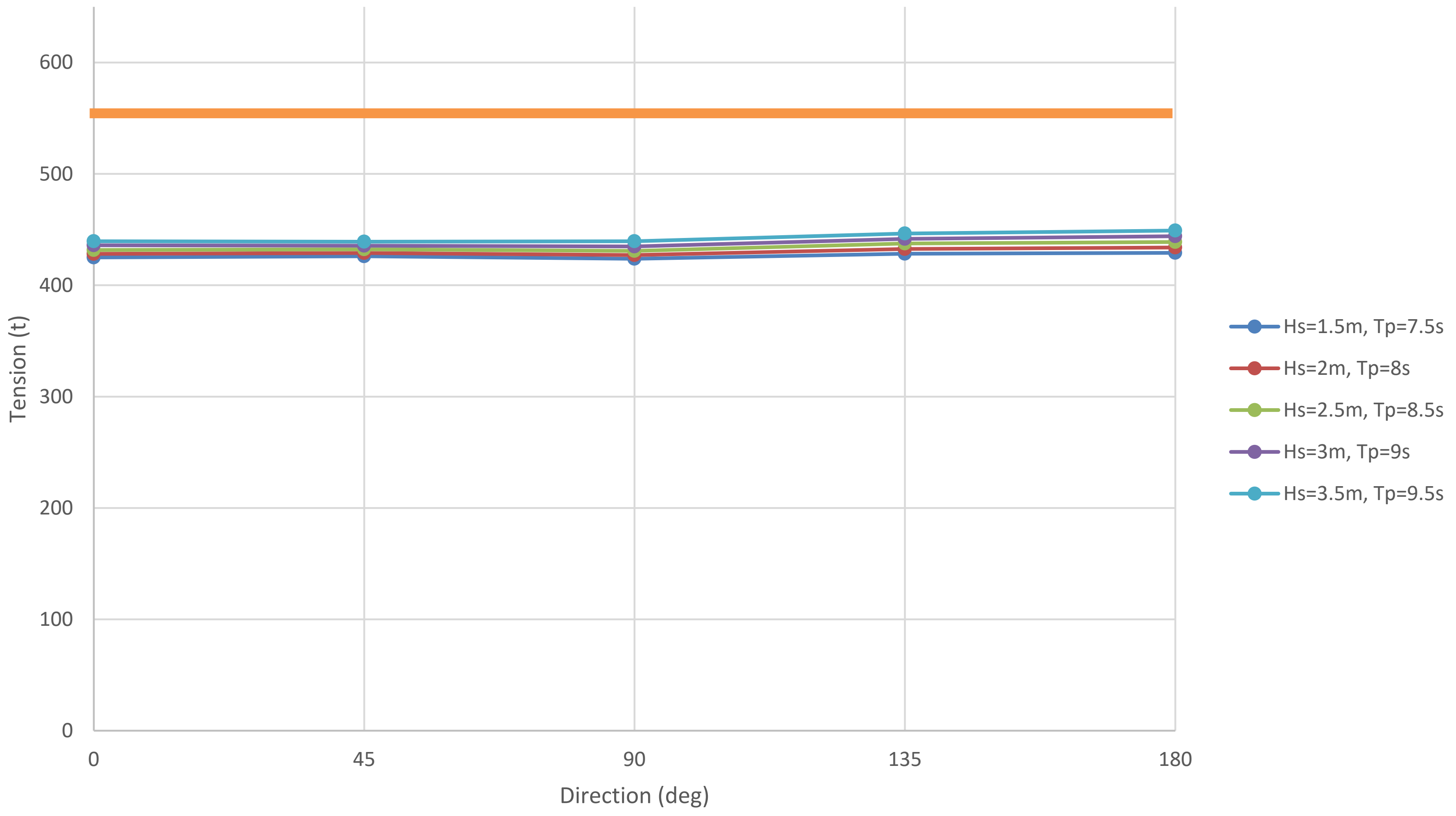




Tension levels corresponds to MPM during 1 hour. Indicate 65% of MBL

# Prelay Test Tensioning

Data modelled for the Island Victory testing anchors to >400te at Solveig




Tension levels corresponds to MPM during 15 minutes. Indicate 65% of MBL

# Key Observations

- The peak loads during test tensioning are **much** less than during retrieval.
- This is mainly due to the line length, which is significantly longer during test tensioning, providing mainly geometric stiffness [catenary] and not elastic stiffness [chain stretch].
- Grounded length ahead of the anchor [e.g. during test tensioning] absorbs load cycles. This allows the sag in the system to compensate for vessel movement rather than relying on stretch in the system.
- A tight line must absorb any motion through material elasticity. Chain is famously inelastic! Catastrophic failure is likely.

# Summary

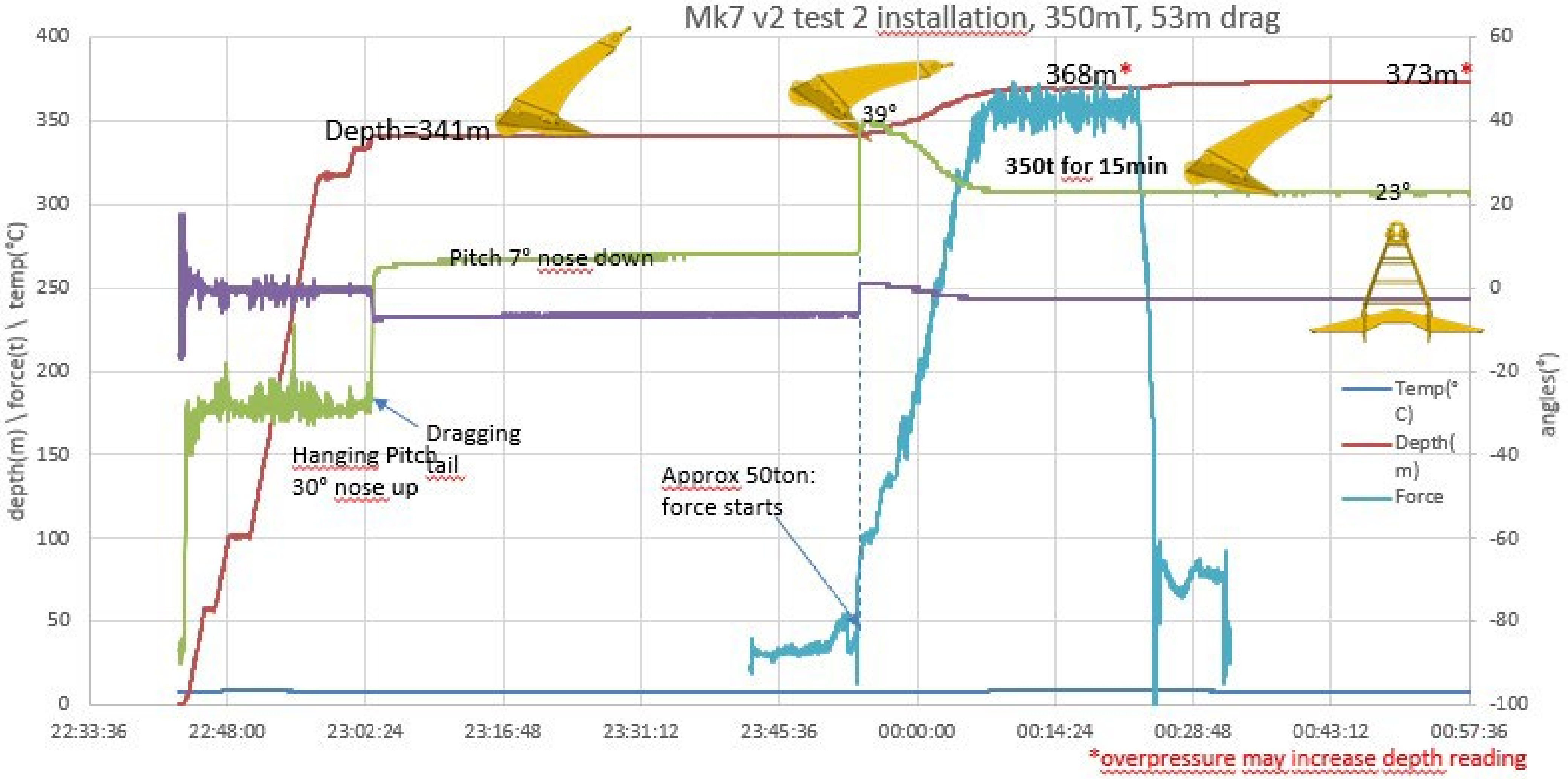
- Retrieval of anchors is a critical operation exposing assets to high peak loads

- Peak tensions are highly dependent on:
  - Pay-out
  - Water depth
  - Wave height and period
  - Wave direction vs vessel

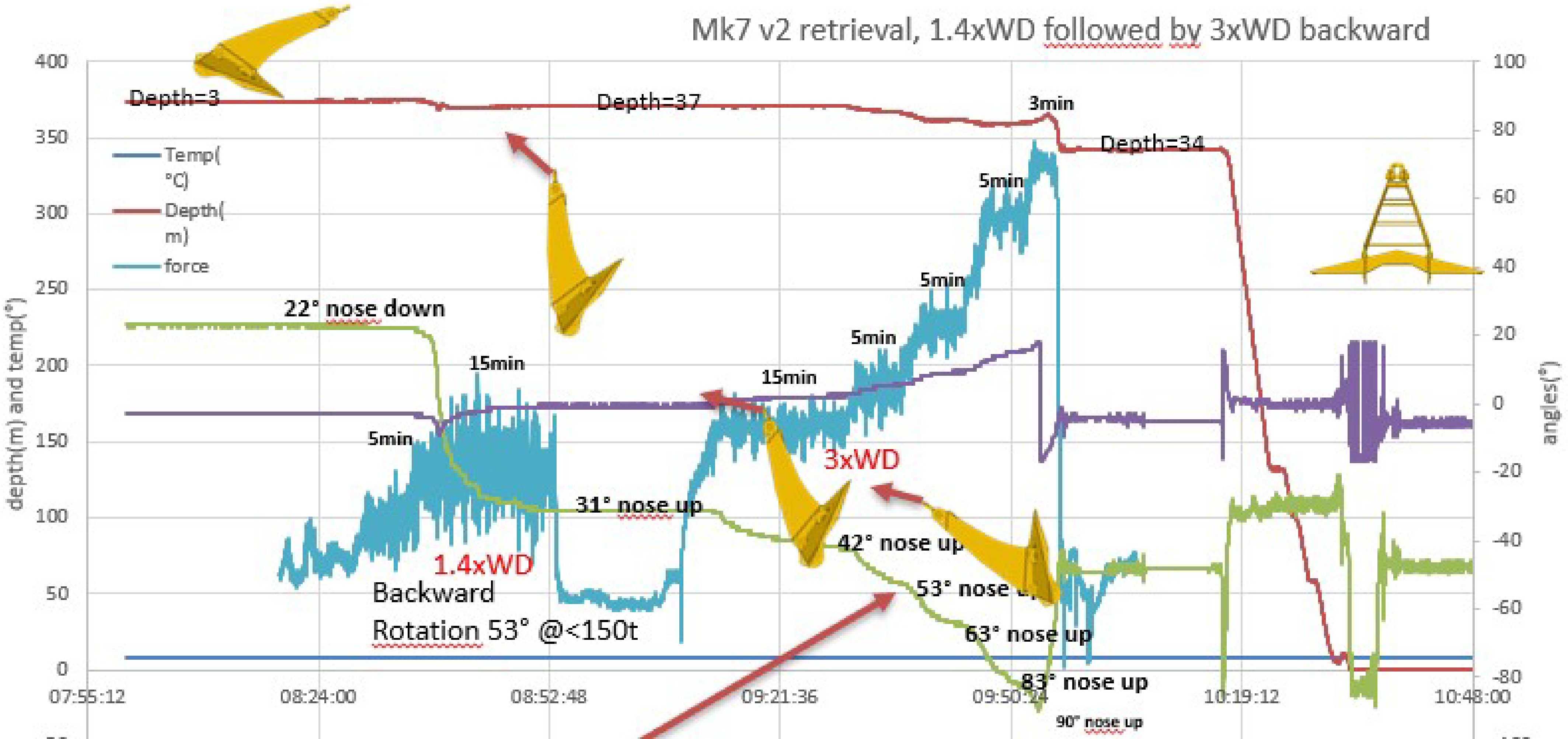
- **NOTE: use of AHV winch rendering function can greatly reduce mooring component attrition** **[PUT A PIN IN THIS ONE – I ANTICIPATE PLENTY OF DISCUSSION LATER]**

# New GOMO / Vryhof Manual procedure using STEVPRIS®Mk7

1. Tested at Troll field with soft clay conditions.
2. Applies to all Vryhof drag-embedment models.
3. Updated spec **STEVPRIS®Mk7 -** matches Mk6 soft soil performance.
4. Regular installation to 350t, hold for 15 min.
5. Backwards retrieval (against the line) on main shackle.
6. Build up to 150t @1.4xWD backwards for 15 min. Anchor should rotate backwards at this limited force.
7. Continue to 150t @3xWD backwards for 15 min and increase pull with steps of 50t / 5min until anchor breaks out. Work wire on stern roller to comply with new DNV regulations.



Mk7 v2 test 2 installation, 350mT, 53m drag
depth(m) \ force(t) \ temp(°C)
angles(°)
Depth=341m
39°
368m*
373m*
350t for 15min
23°
Pitch 7° nose down
Dragging tail
Hanging Pitch 30° nose up
Approx 50ton: force starts
Temp(°C)
Depth(m)
Force
400
350
300
250
200
150
100
50
0
60
40
20
0
-20
-40
-60
-80
-100
22:33:36
22:48:00
23:02:24
23:16:48
23:31:12
23:45:36
00:00:00
00:14:24
00:28:48
00:43:12
00:57:36
*overpressure may increase depth reading

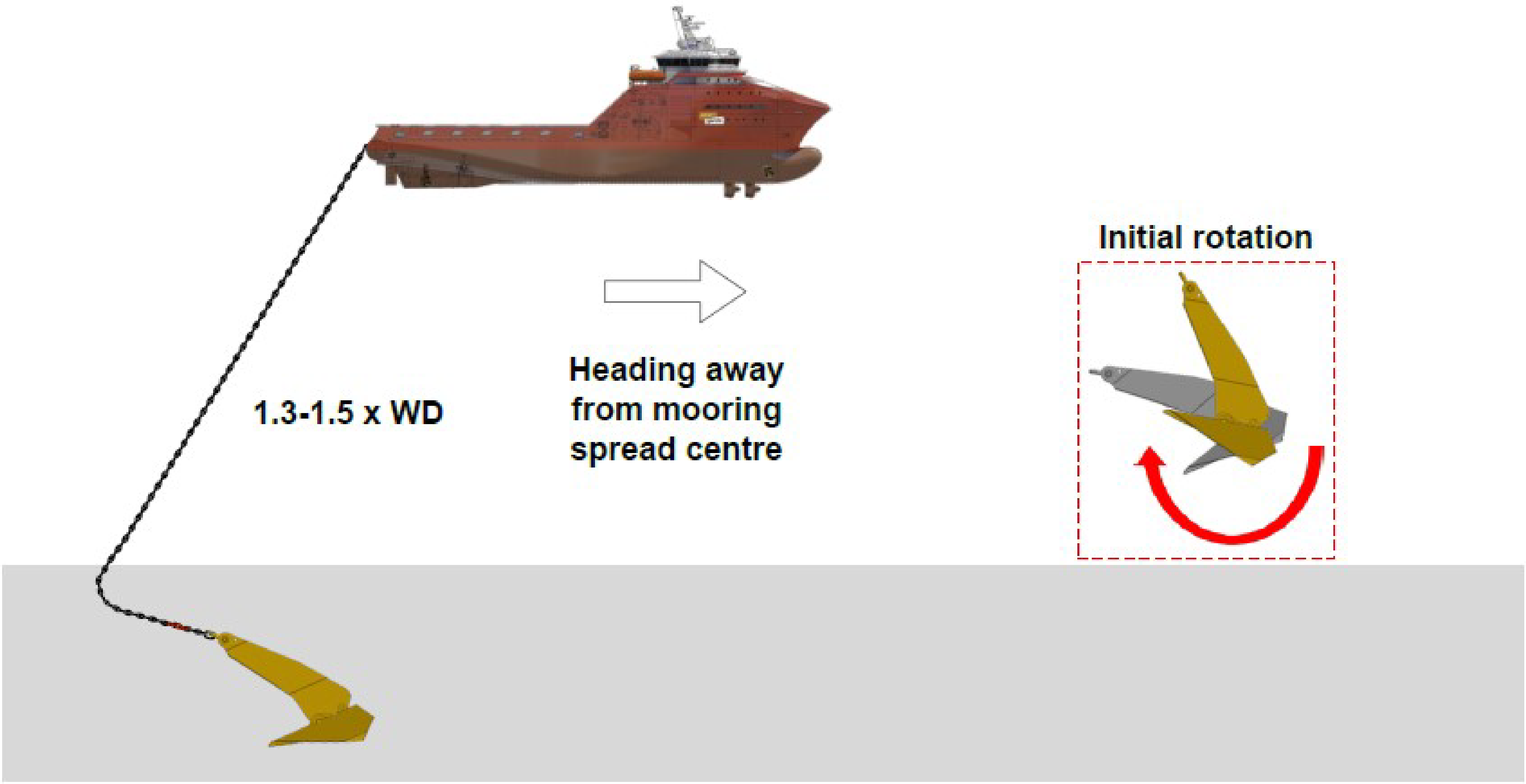



Rotation follows 15min steps quite smoothly, 5min timing looks correct!

# Retrieval sequence

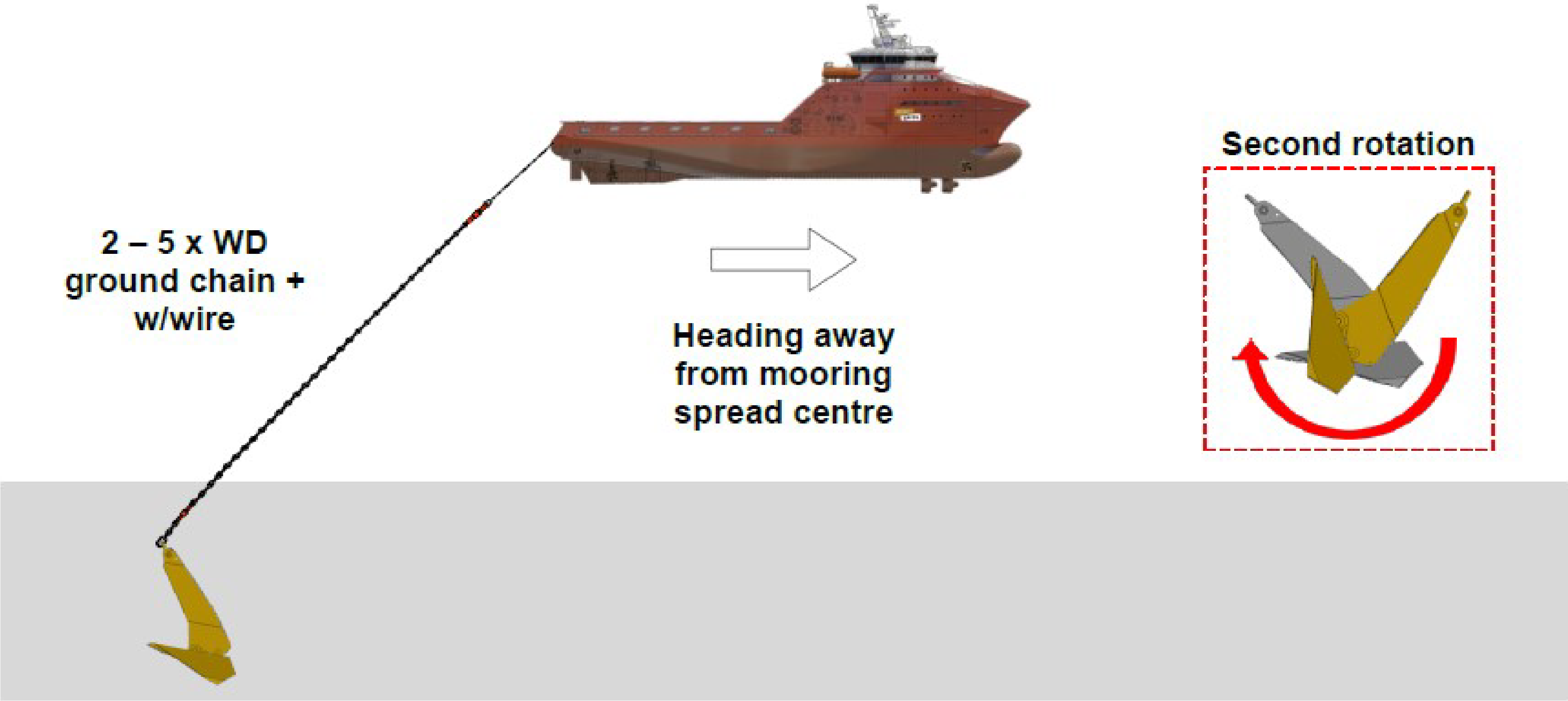
<table>
<tr><th colspan="4">Operational phases</th></tr>
<tr><td colspan="4">When pulling an anchor out backwards, the number of phases of the operation is dependent on how deep the anchor is buried.</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Initial dislodgement [15-30 minutes]</td><td colspan="2">1.3–1.5 x WD.</td></tr>
<tr><td rowspan="2">Low power</td><td><30% MBL of mooring chain if it is on the roller.</td></tr>
<tr><td>100-150Te to allow liquefaction / equalisation beneath fluke.</td></tr>
<tr><td colspan="4">For an anchor at the mudline, phase 1 successfully executed will often break the anchor out cleanly.</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Second rotation [15-30 minutes]</td><td colspan="2">2-5 x WD.</td></tr>
<tr><td colspan="2">Usually w/wire on roller [higher tensions can be applied with w/wire on roller].</td></tr>
<tr><td colspan="2">100-150Te to allow liquefaction as anchor rotates.</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Translation</td><td colspan="2">2-5 x WD.</td></tr>
<tr><td colspan="2">Usually w/wire on roller.</td></tr>
<tr><td colspan="2">Higher tension – increase power in 50Te / 5 minute increments.</td></tr>
</table>

## Figure 1 – Initial Rotation [phase 1]

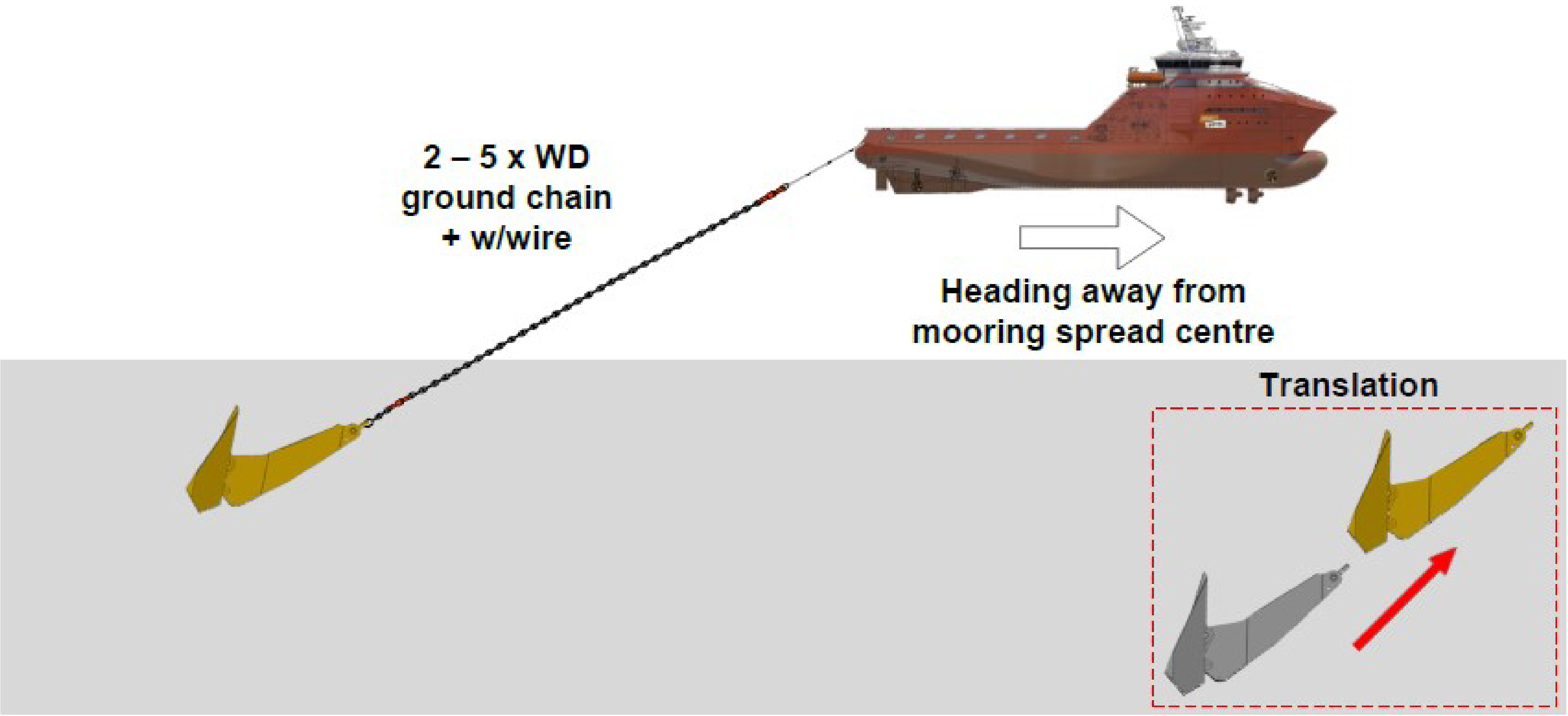


# Length of 2-5 allows length adjustment to keep R5 chain off the stern roller

**Figure 2 – Second Rotation [phase 2]**



## Figure 3 – Translation [phase 3]



# FAQs

1. We’ve had good results pulling anchors out forwards. Is this not recommended?

2. We’ve had good results pulling anchors forwards then backwards. Is this not recommended?

3. What’s wrong with just ripping it straight out? That’s what we always used to do.

4. Using tension control in shallow water with approx. 1.5x WD creates a high risk of over-speeding the winch.

First of all, I should stress that this recommended method is designed to apply to all Vryhof drag anchors, in all settings, in all seabed conditions:

- If you are sent out to retrieve an anchor that was installed years ago and no one knows the settings / installation load etc.
- Step-by-step for a completely inexperienced crew.

It is of course possible to create job-specific retrieval procedures, tailored to the specifics of the case – for example, we achieved very good results pulling Stevshark REX anchors [sand angle, installed at >400te] out forwards.

If you have settled upon a method that fits the specifics of your particular mooring design, I’m not telling you to throw all that out and start following our method.

**This guidance, like all the guidance found in the Vryhof Manual or GOMO, is provided as a baseline that will work in all circumstances should installation data be missing / incomplete or if an inexperienced crew is used.**

# Pulling anchor out forwards

It is common in the North Sea to pull anchors out “forwards” – i.e. towards well centre.

This is often a good solution for shallow-embedded anchors set to the SAND angle:

1. Not much uplift required to angle the flukes towards the surface
    a. Can be achieved with an acceptable [i.e. not too short] line length – 1.5 - 2x WD
2. Line never has to hang slack
3. AHV always pulling in same direction – no heading change
4. Shallow embedment means lower breakout tensions can be expected when compared to using this method on a deeply-embedded anchor

Disadvantages of pulling forwards:

1. Only suitable at SAND angle
   a. **If the info on installed angle is incorrect, you could be wasting your time.**
2. High tensions
   a. When successful, this method requires higher tensions to break out an anchor [compared to pulling out backwards].
   b. Tension applied on fore/aft axis of anchor [strongest aspect], but the consequences of any loss of station will be higher due to power setting.
   c. A shorter line will apply more uplift, reducing the load required to break out the anchor, BUT an excessively short line exposes the system to unmanageably high dynamic forces.
3. Time
   a. Ordinarily this method will take longer than breaking out backwards – AHVs must be patient and resist the temptation to apply excessive power.

# Pulling forwards then backwards

Issues to be aware of:

1. Shank twisting risk described earlier in the presentation [unlikely but possible].
2. The first phase [pulling forwards] is less effective at liquefying the surrounding soil as it does not promote rotation
   a. Angle of pull will be a few degrees off the axis of the anchor; this is less effective at creating a void beneath the fluke which can be allowed to fill with water, promoting liquefaction.
3. An anchor set to INTERMEDIATE or MUD angle will probably embed further if it moves at all.

# Ripping anchor out directly [i.e. no rotation]

If the anchor is not allowed time to rotate, it will translate [i.e. transit out of the seabed] in its initial orientation. This will increase loads for two reasons:

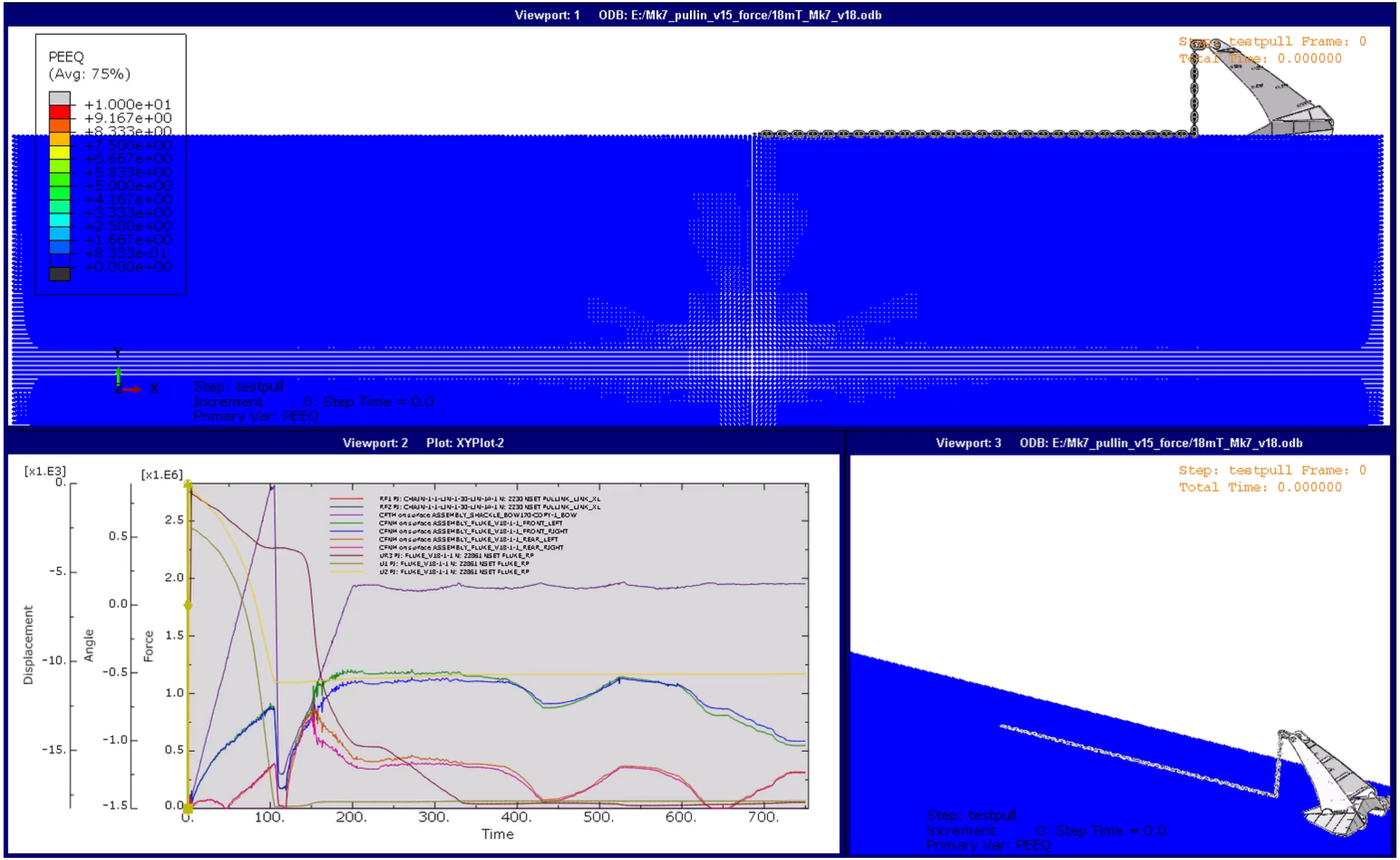
1. Larger volume of soil increases overall displacement.

2. Failure to allow liquefaction means friction will be high.

**Also: Sub-optimal orientation makes structural failure more likely.**

# Shear zone – when the anchor can rotate in the mud

# Abaqus software simulation [uniform non-layered soil]



# Use of winch rendering function

The rendering function on a winch allows it pay out when a set tension is exceeded. In a perfect world, this will be a controlled process which allows the plant to absorb any load spikes while functioning within its design limits.

**HOWEVER,** over-speeding the winch is a risk. Due to the lack of sag in a shallow-water system, the risk of over-speed is relatively high in the standard North Sea conditions most of us operate in.

# Use of winch rendering function

My advice is focused on how to minimise mooring equipment attrition. However, in my previous life I was far more interested in reducing AHV plant attrition, so I understand the conflict!

I accept that you know the limits of your vessel better than I do, but I urge you to assess the use of winch rendering as a viable way to reduce mooring equipment damage.

# At this point, I invite any questions / thoughts / insults / projectiles

**[I may regret this]**