

"Development of the ARCA, a diverless chain connector for the high integrity of mooring lines"

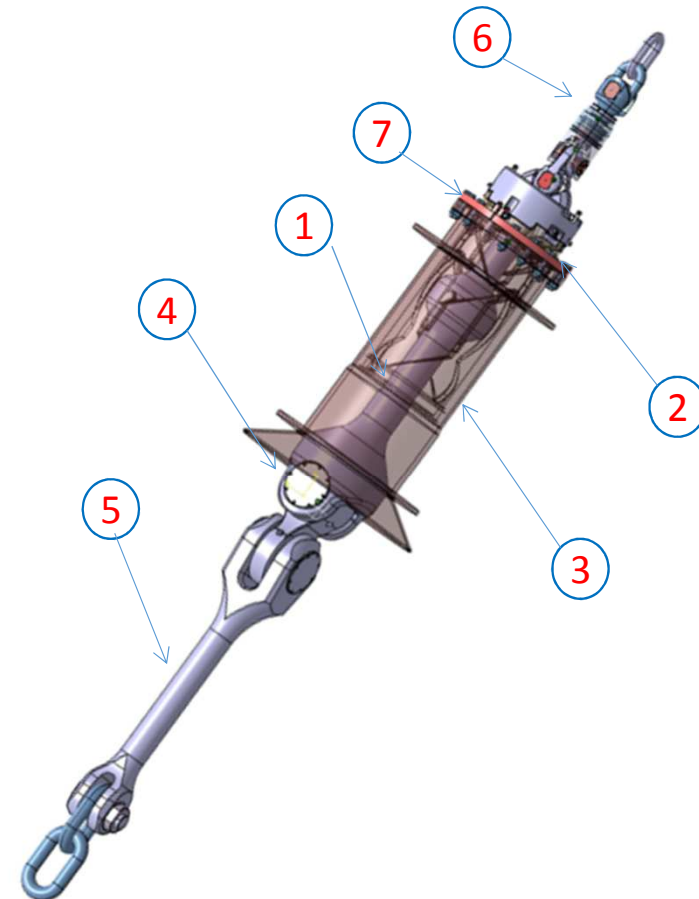
Christian Bauduin - Mauro Bedini
SBM offshore



ARCA – Articulated Rod Connecting Arm - Definitions

Constituted of:

1. A rod
2. A receptacle to hold the rod's head
3. A cam sleeve to guide the rod through connection/disconnection
4. A unijoint at the rod's bottom
5. A lever arm to satisfy chain OPB requirements
6. An articulation on the install line
7. Load cells for mooring line load monitoring.

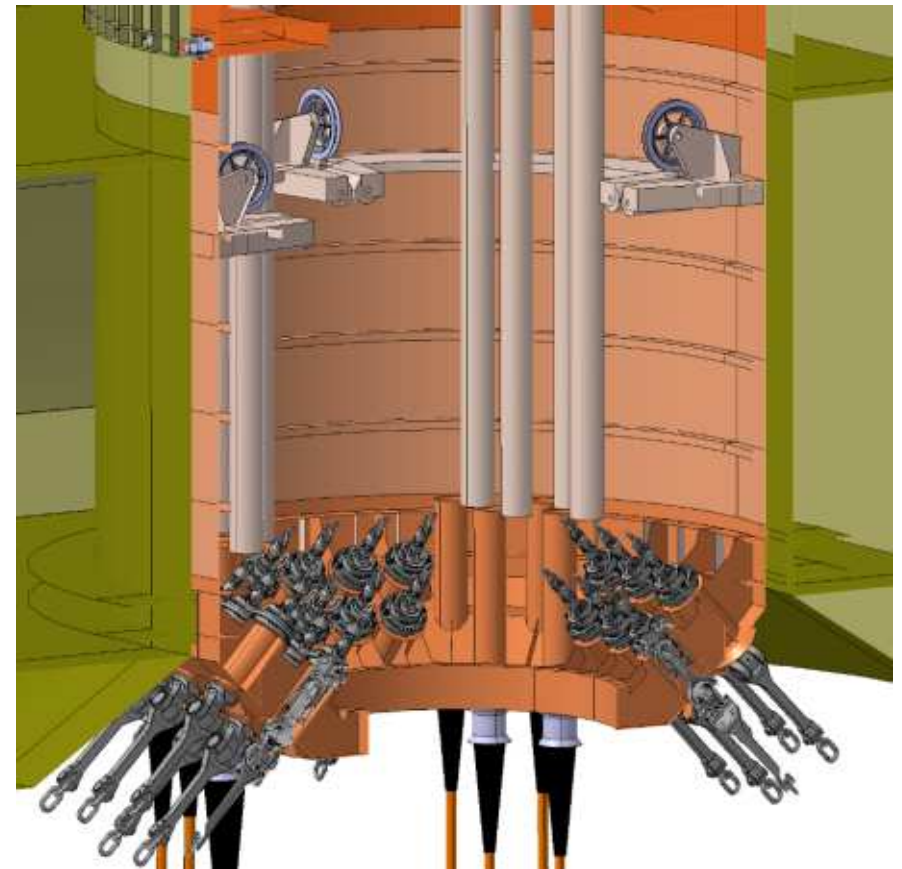


ARCA – Articulated Rod Connecting Arm – how it works



Why we developed it?

- Allows diverless offshore connection and disconnection.
- Allows inspection, maintenance and replacement of the articulation.
- Separates structural (I-tubes) from mechanical function (articulation).
- Can lead to room savings in turrets.
- Maintains a flush keel at yard for easy integration.
- No seafastening before hook up.
- Allows installation and replacement of a more reliable Anchor Leg Load Monitoring System.



Why full scale testing?

- The performances of the cam for rotation have been extensively tested at 1/10 scale .

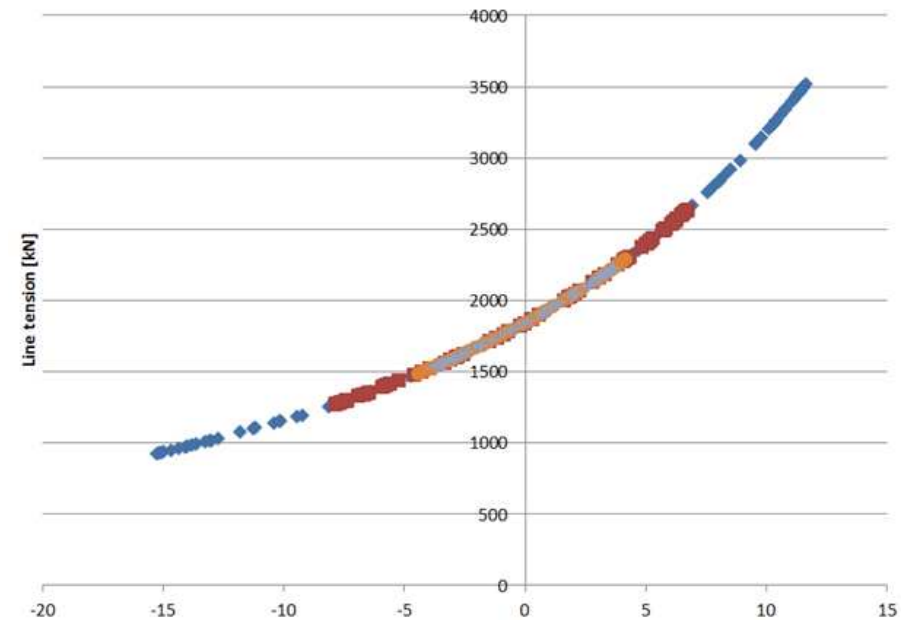


- However, the need for full scale testing was identified to correctly assess performances under real conditions in terms of:
 1. Contact pressures
 2. Friction coefficient
 3. Gaps
 4. Manufacturing tolerances
 5. Loads (pretension and winch pull)

What do we test?

1. The functionality envelope for connection/disconnection of the ARCA as a function of:
 - Line tension
 - Misalignment angle
2. The overpull needed at winch for installation

Example of ARCA misalignment angle vs line tension for a given mooring system



- ◆ 3 lines-3.7m HS
- 3 lines-2.5m HS
- 6 lines-3.7m HS
- + 6 lines-2.5m HS



Test bench capabilities:

- Able to simulate line inclination of 30 ° to 70 °
- Line/receptacle misalignment of +25/-19 °
- OP angles simulated with cam rotation.
- Pretension simulation up to 200 tons.
- Pretension nearly constant during connection.
- Winch overpull simulation at chain table up to 200 tons
- Installation stroke over 6 meters.
- Simulated line twisting torque.

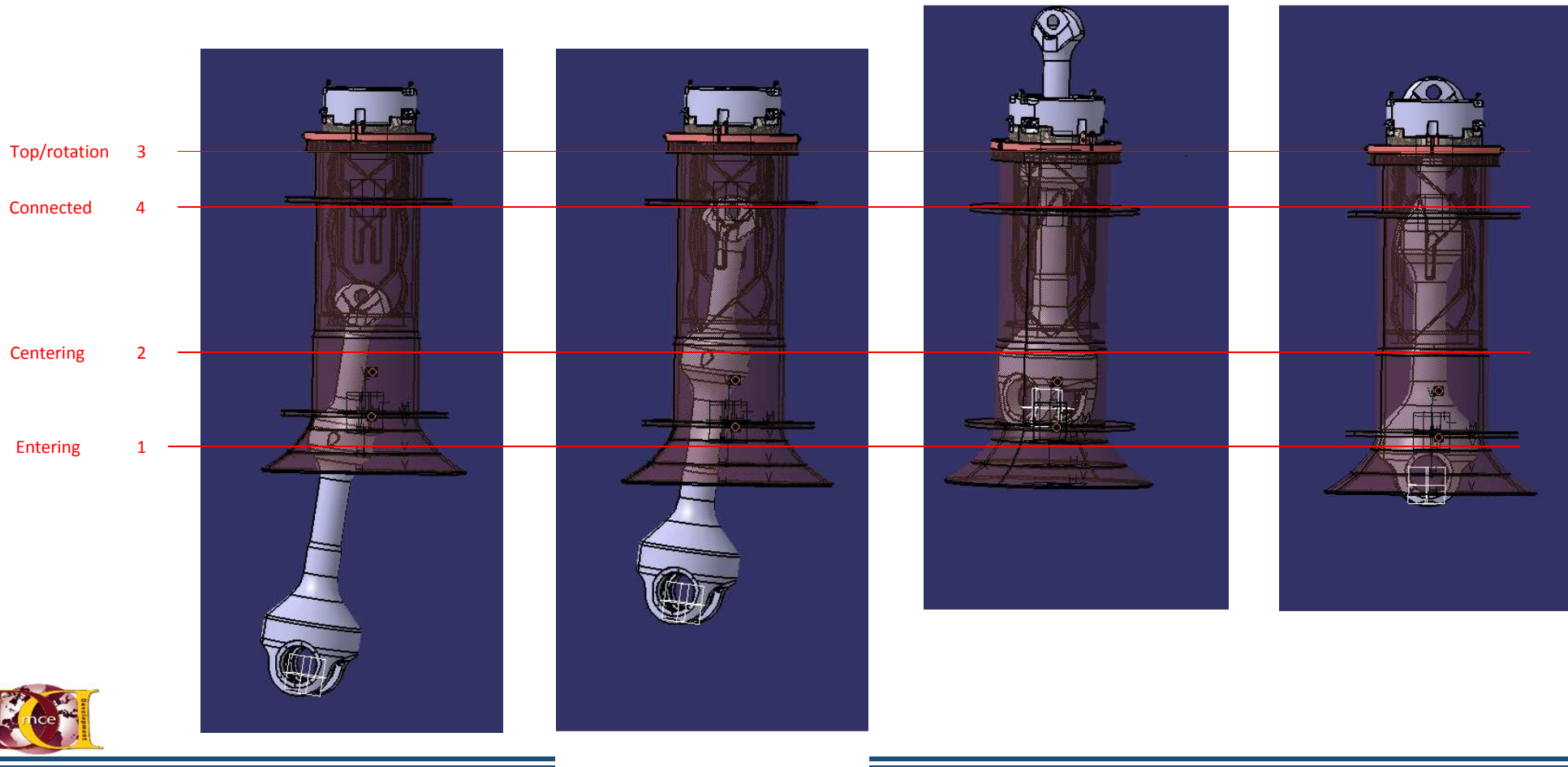


- More than 220 connection/disconnection tests have been performed on the prototype up to now.
- During a 40 year design life a maximum of one connection / disconnection every 5 years is expected for inspection.

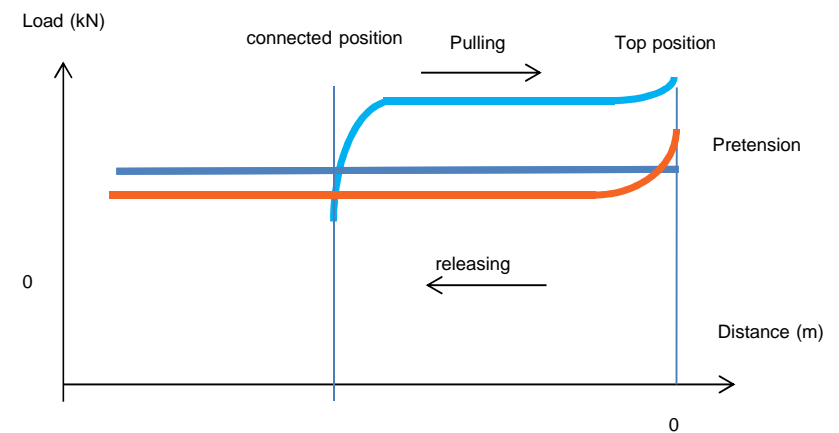
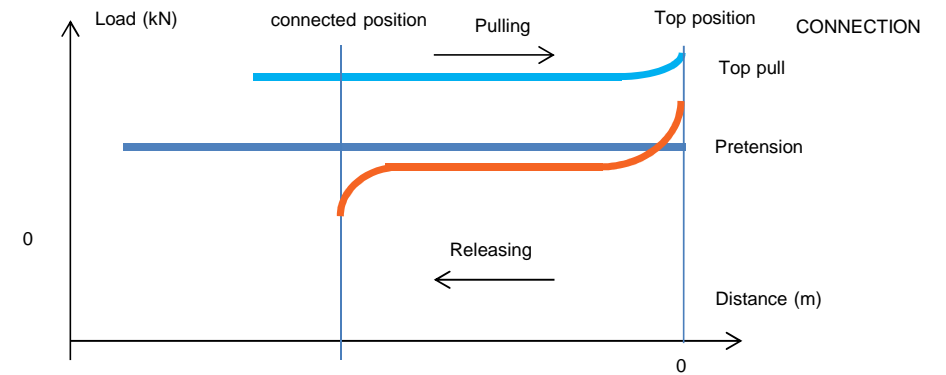
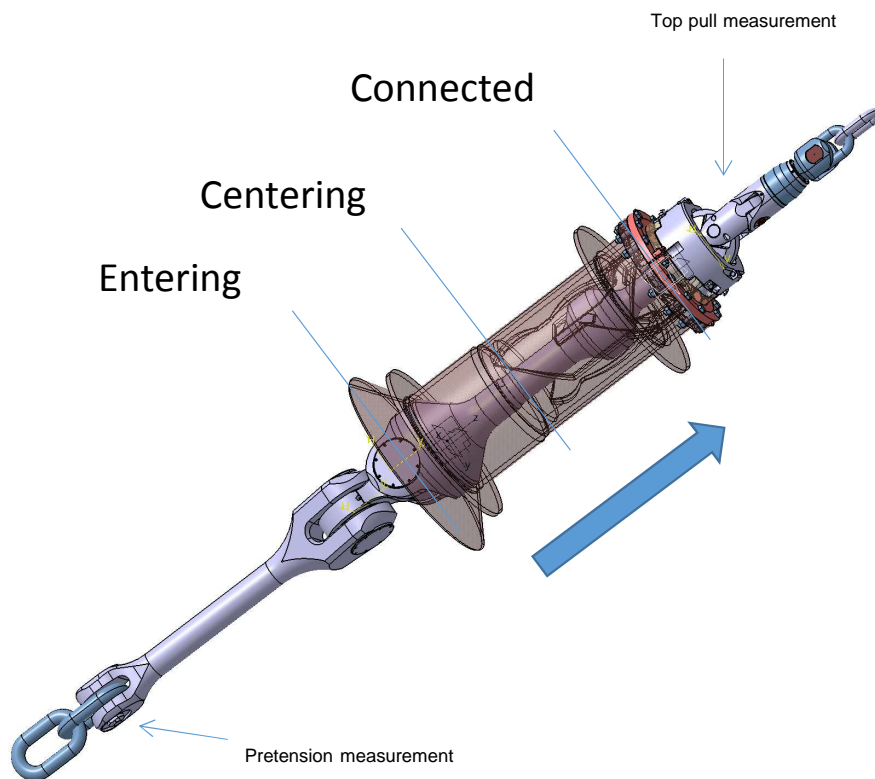
	date	resulting receptacle inclination	resulting mooring line inclination	TW	IP	OP
		deg	deg	deg	deg	deg
1	1/28/2015	90	90.00	0	0.00	0
2	1/29/2015	70	70.00	0	0.00	0
3	1/29/2015	50	42.94	0	7.06	0
4	1/29/2015	57	40.06	0	16.94	0
5	1/29/2015	57	40.06	0	16.94	0
6	1/29/2015	61	38.41	0	22.59	0
7	2/4/2015	55	45.12	0	9.88	0
8	2/4/2015	55	45.12	0	9.88	0
9	2/4/2015	55	45.12	0	9.88	0
10	2/4/2015	55	45.12	0	9.88	0
11	2/5/2015	55	40.18	0	14.82	0
12	2/5/2015	55	40.18	0	14.82	0
13	2/5/2015	55	40.18	0	14.82	0
14	2/5/2015	55	40.18	0	14.82	0
15	2/5/2015	55	35.24	0	19	0
16	2/5/2015	55	35.24	0	19	0
17	2/5/2015	55	35.24	0	19	0
18	2/5/2015	55	35.24	0	19	0
19	2/5/2015	55	29.59	0	25	0
20	2/5/2015	55	29.59	0	25	0
21	2/5/2015	55	29.59	0	25	0
22	2/5/2015	45	30.18	0	14	0
22	2/6/2015	45	54.88	0	-9	0
23	2/6/2015	45	54.88	0	-9	0
24	2/6/2015	45	54.88	0	-9	0
24-Feb	55	55	0	1200	0.0	0
24-Feb	55	43	12	1200	0.0	12
24-Feb	55	43	12	1800	0.0	12
24-Feb	55	40	15	1200	0.0	15
24-Feb	55	40	15	1800	0.0	15
24-Feb	55	34	20	1200	0.0	20
24-Feb	55	34	20	1800	0.0	20
24-Feb	55	65	-10	1200	0.0	-10
24-Feb	55	65	-10	1800	0.0	-10
24-Feb	55	70	-15	1200	0.0	-15
24-Feb	55	70	-15	1800	0.0	-15
24-Feb	55	75	-20	1200	0.0	-20
24-Feb	55	75	-20	1800	0.0	-20



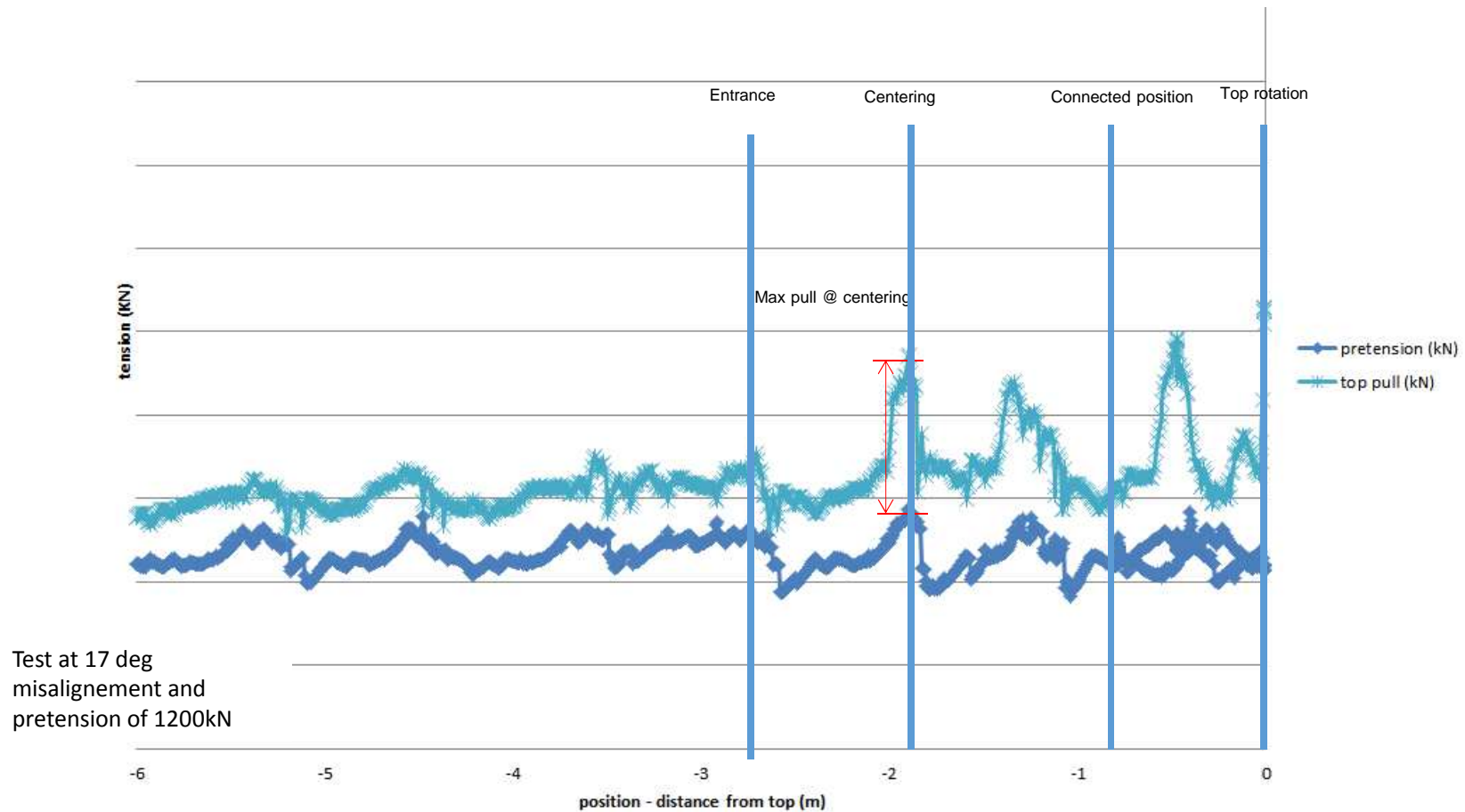
- Tensions and overpull data are collected constantly over time, to identify key points during pulling.



- Loads are plotted as a function of position to identify the points where friction is higher in the system.



- The typical shape of a real test data is shown below.
- Maximum winch pull is evaluated and recorded for each combination of in plane and out of plane misalignments.



■ Test bench – prototype operation



Full scale tests phases and product improvements

Phase 1

Validation of the rotation as per defined envelope, but problems at entrance.

Modification: smoother skirt, cam bottom and rod pins shape.

Phase 2

Better entrance ok up to 10-15 degrees.

Decoupling between pins orientation and articulation shafts.

Phase 3

Entrance validated up to 25 degrees. High friction at centering.

Self aligning cam sleeve.

Phase 4

Validation of performances , with severe wear and rusted surface, with simulated marine growth.



Status

- Performance envelope achieved at phase 4.
- Endurance of the system is proven (more than 220 connections in extreme configurations for an expected maximum of 8 connections in design life).
- Large part of testing campaign has been performed with severe rust and wear.
- Large functional gaps ensure high tolerance to wear, corrosion and marine growth.

Next steps

- Fine characterization of friction to determine winch capacity on projects.
- Test with simulated marine growth to be performed.
- Finalization of the qualification dossier with classes.

