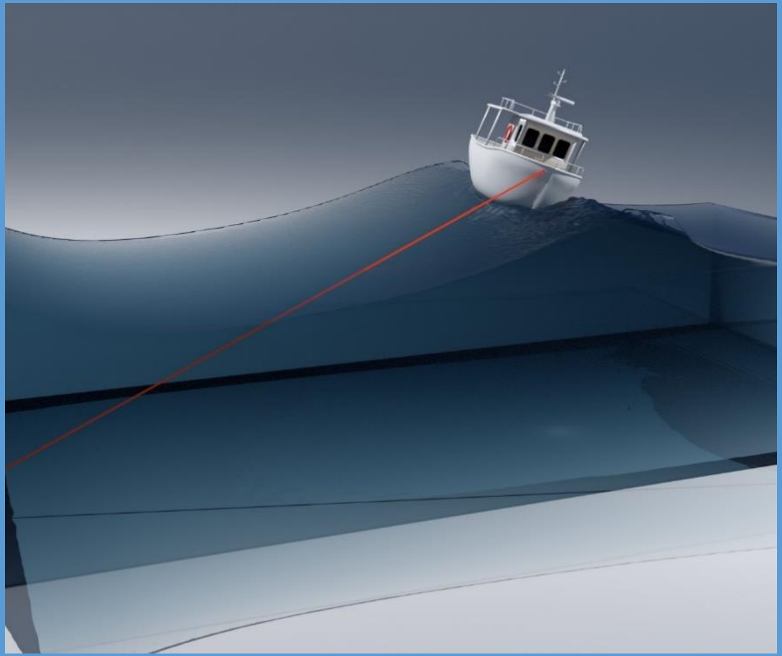
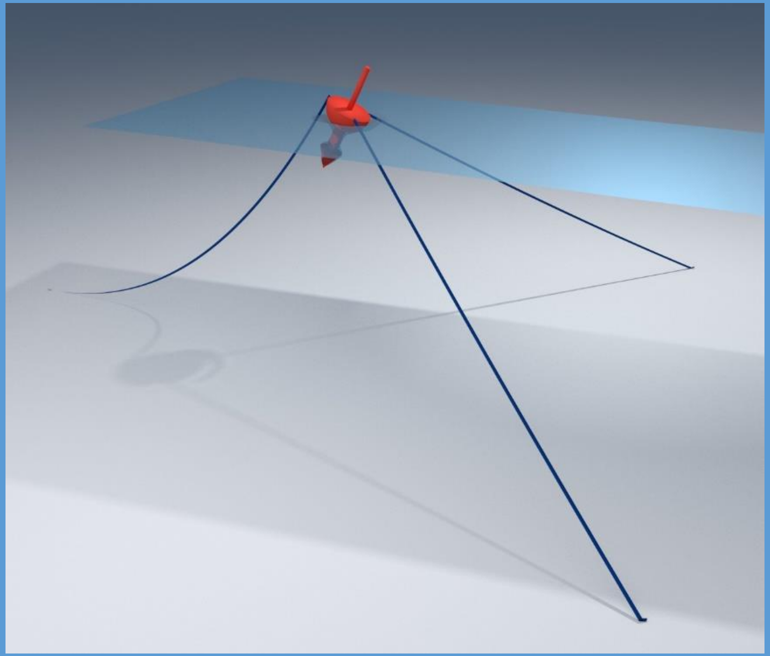
Mooring implementation in SPH models





A. Barreiro, J.M. Dominguez, A.J.C. Crespo, O. Garcia-Feal and M. Gomez-Gesteira

anxo.barreiro@uvigo.es, Iberian SPH workshop, Dec 2015

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Floatings & Moorings

Floatings & Moorings

All the objects are floating in the water and moored, thus a proper formulation is needed and must be validated.

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Floatings & Moorings

Each particle *k* (FB) experiences a force per unit mass given by $\boldsymbol{f}_k = \sum_{a \in WPs} \boldsymbol{f}_{ka}$

Where $\boldsymbol{f}_{ka}$ is the force per unit mass by the fluid *a* on particle *k*,

$$m_k \boldsymbol{f}_{ka} = -m_a \boldsymbol{f}_{ak}$$

Newton's equations for **rigid body dynamics**:

$$M \frac{d\boldsymbol{V}}{dt} = \sum_{k \in BPs} m_k \boldsymbol{f}_k$$

$$I \frac{d\boldsymbol{\Omega}}{dt} = \sum_{k \in BPs} m_k (\boldsymbol{r}_k - \boldsymbol{R}_0) \times \boldsymbol{f}_k$$

$$\boldsymbol{u}_k = \boldsymbol{V} + \boldsymbol{\Omega} \times (\boldsymbol{r}_k - \boldsymbol{R}_0)$$

The movement of FB is derived by considering its interaction with fluid particles and using these forces to drive its motion

Floatings & Moorings

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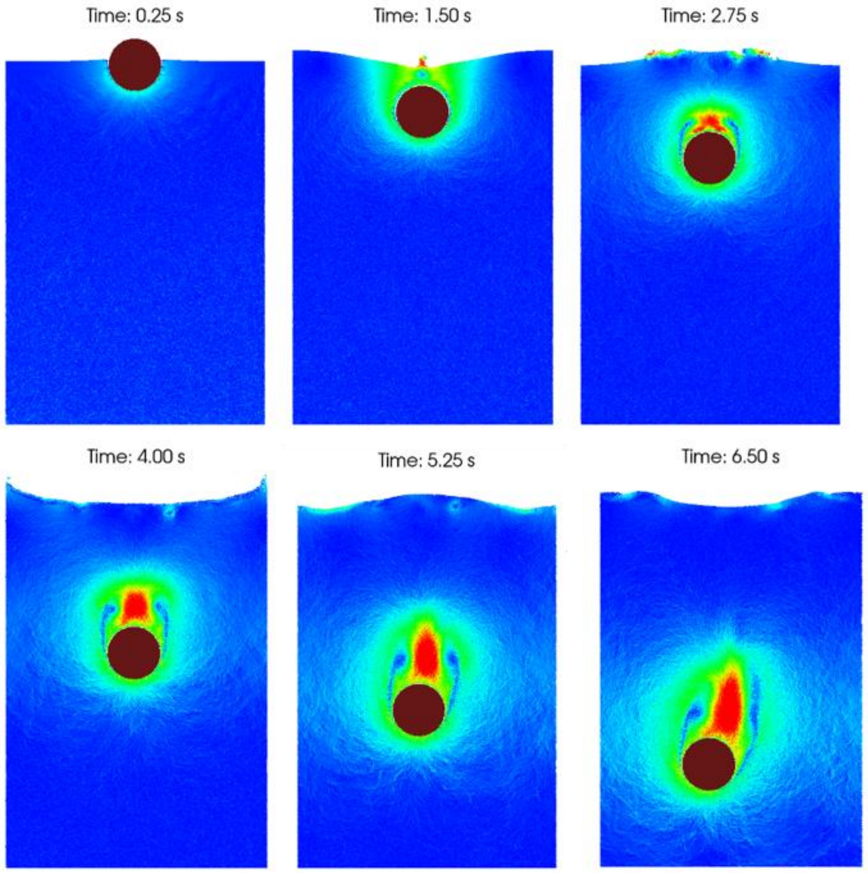
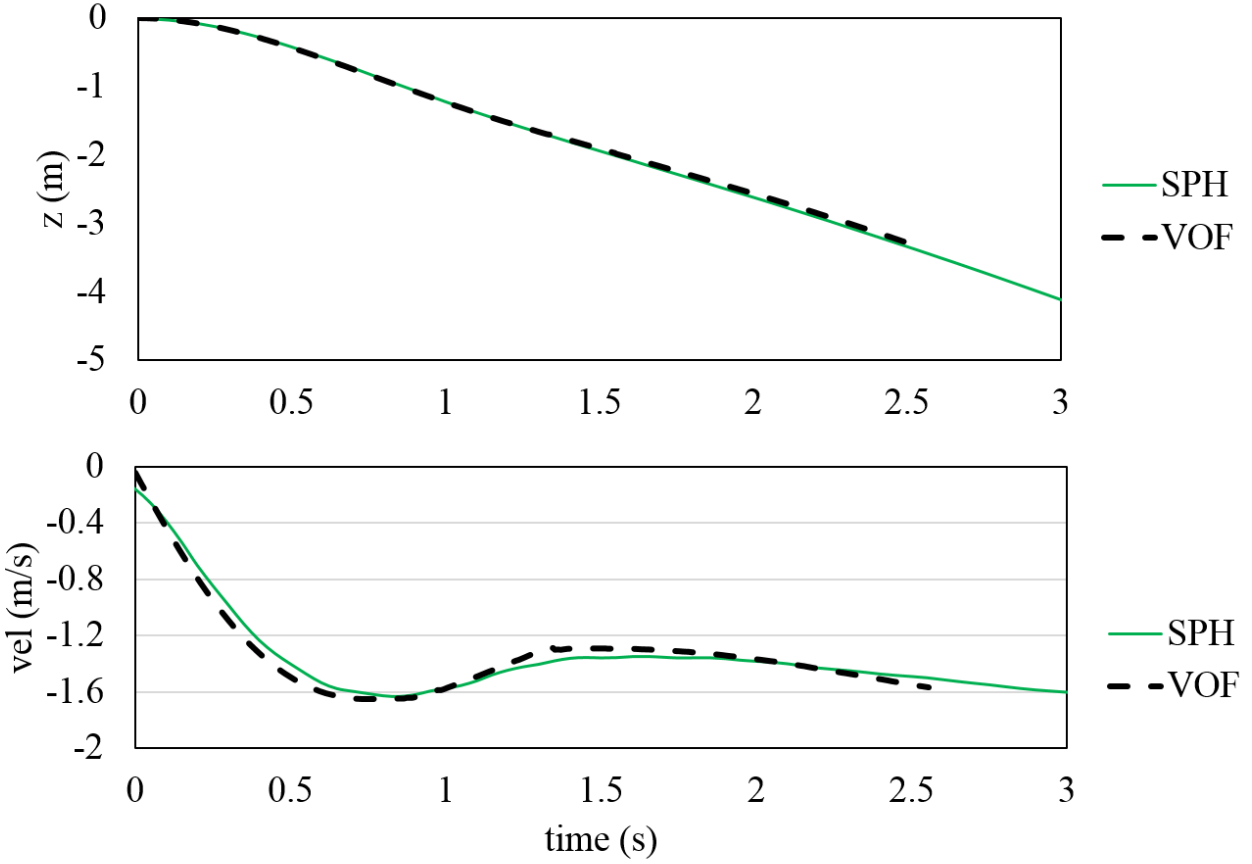
Validation for floating objects



$\rho_{object} = 1{,}200\ \mathrm{kg} \cdot m^{-3}$

Comparison of **numerical data** and **DualSPHysics** results for **displacement** and **velocity** of the sinking cylinder.



Fekken (2004) & Canelas et al. (2015)

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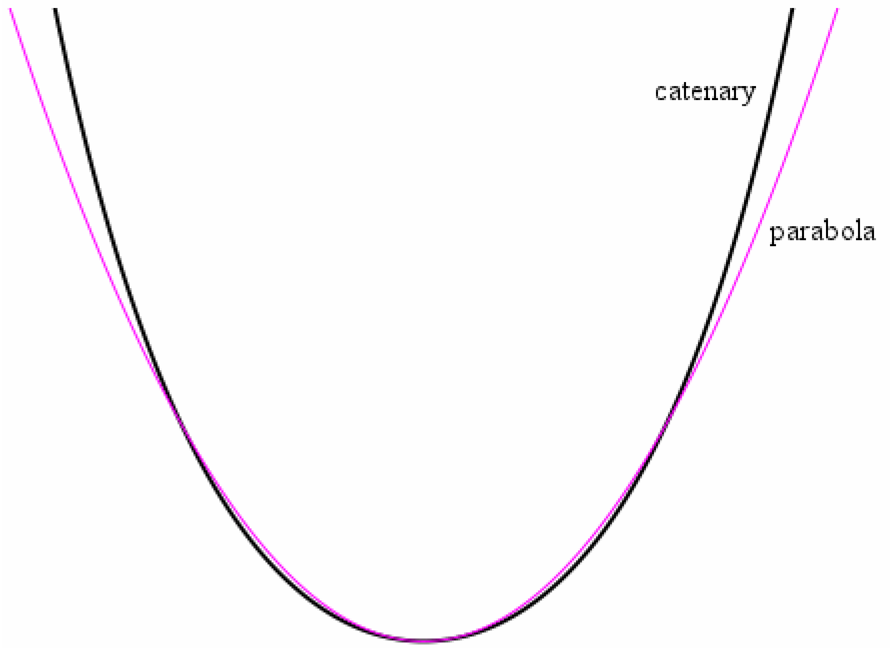
Catenary function $y = \xi \cosh\left(\frac{x}{\xi}\right)$



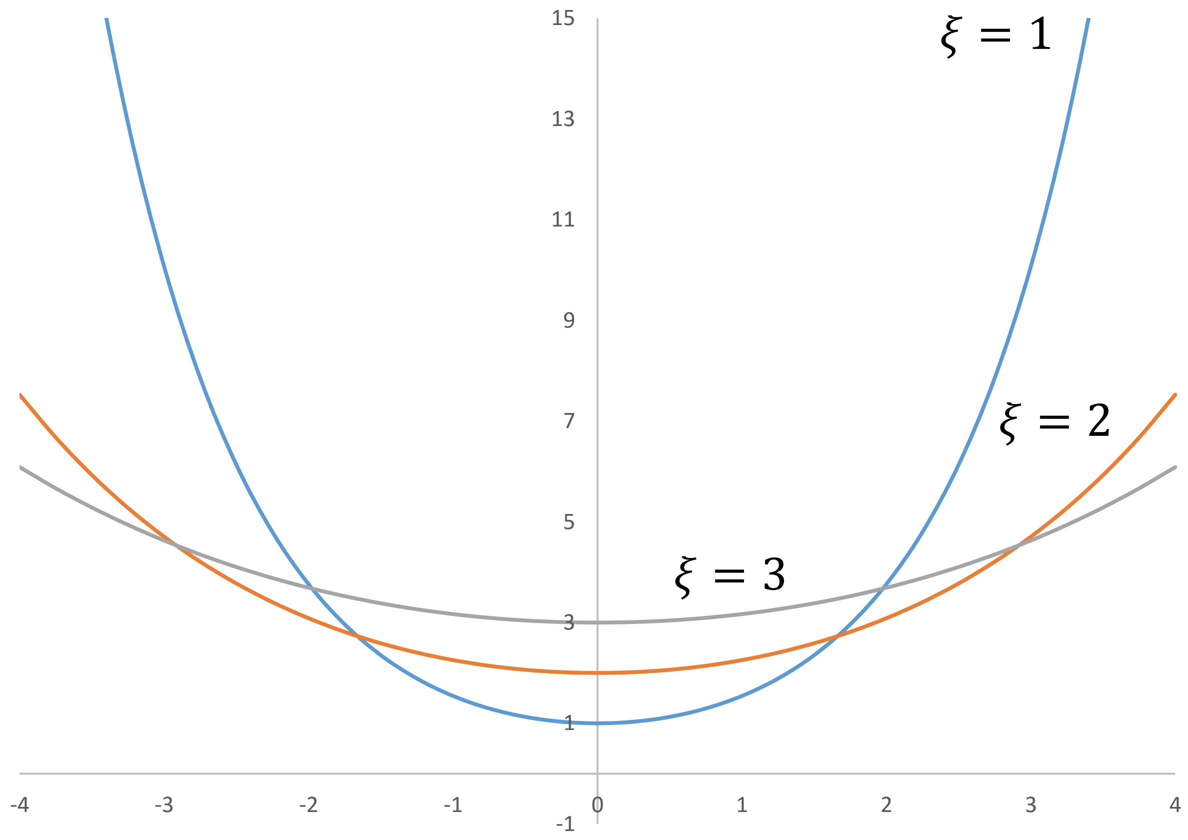


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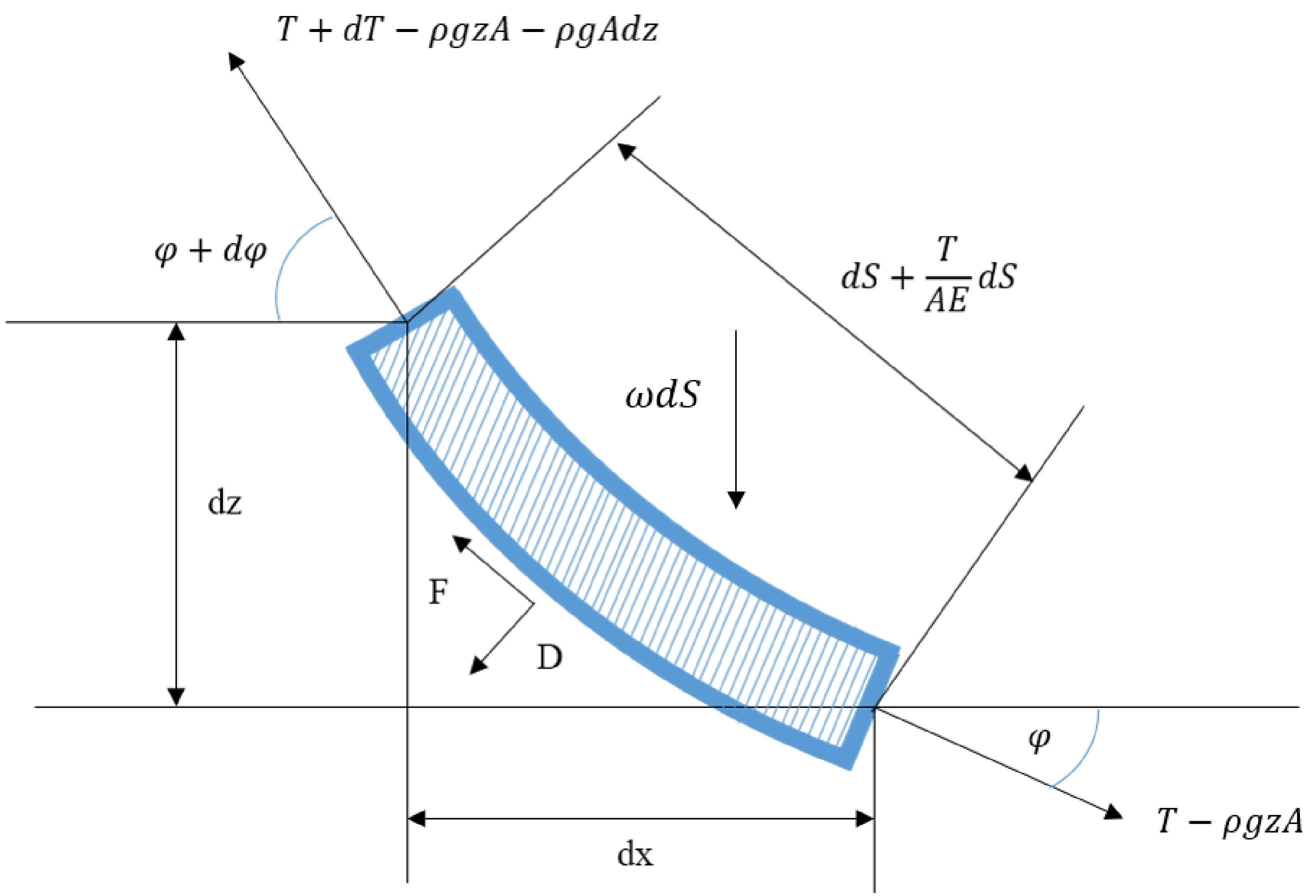
Diagram of the different forces acting on an element of a mooring line



T is the line **tension**.

A is the **cross-section** area of the line.

E represents the **elasticity modulus**.

F and ***D*** correspond to the **mean hydrodynamic forces** both normal and tangential direction respectively.

ω is the **submerged weight** per unit length.

Floatings & Moorings

$$dT - \rho g A\, dz = \left[\omega \sin\phi - F\left(1 + {}^{T}/_{(AE)}\right)\right] ds$$

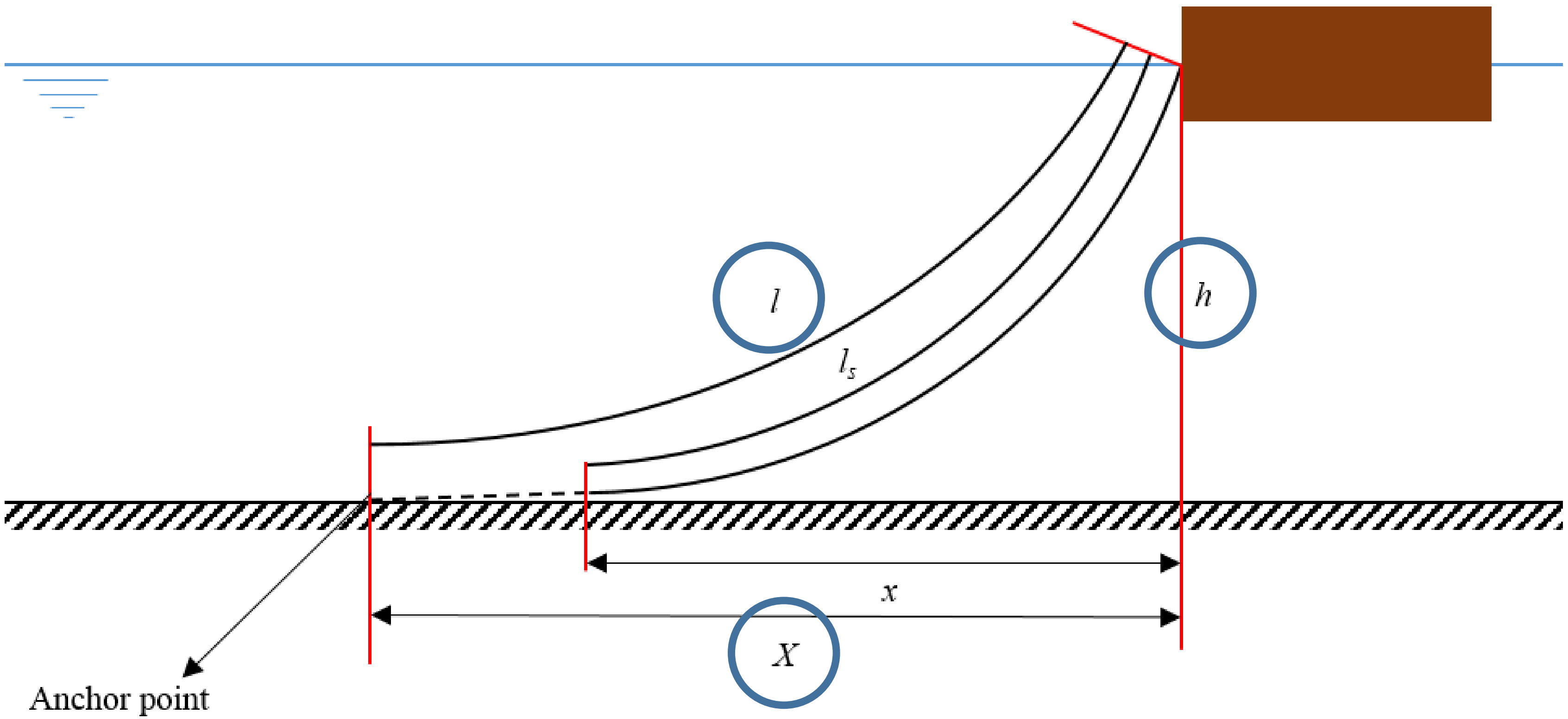
$$T\, d\phi - \rho g A\, d\phi = \left[\omega \cos\phi + D\left(1 + {}^{T}/_{(AE)}\right)\right] ds$$

Faltinsen (1993)

The **tension exerted by a mooring** on a **floating body** can be expressed as:

$$T = T_H + \omega h + (\omega + \rho g A) z$$

Parameters that define a mooring line.



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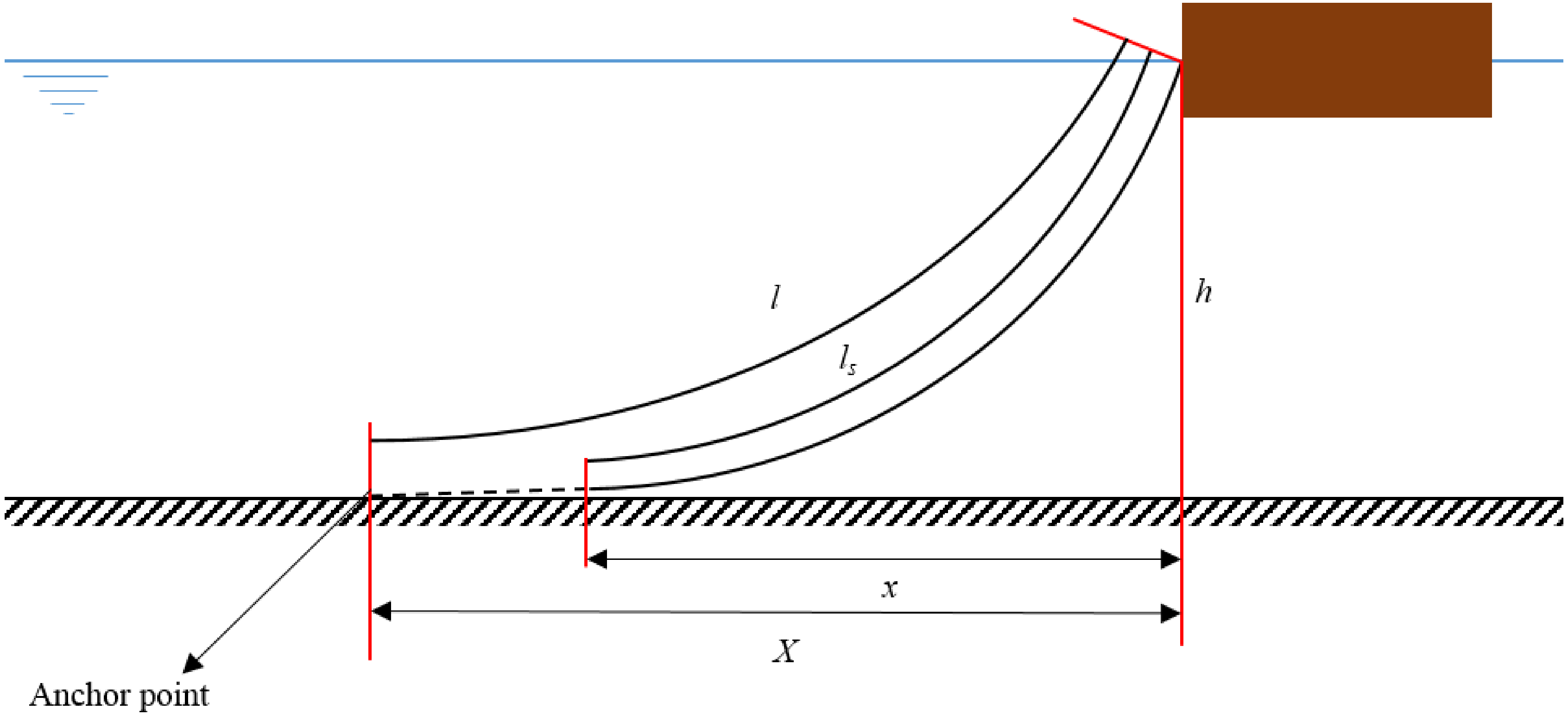
Parameters that define a mooring line.

$$a = {}^{T_H}/_{\omega}$$

$$X = l - h\left(1 + 2\frac{a}{h}\right)^{\frac{1}{2}} + a\cosh^{-1}\left(1 + \frac{h}{a}\right)$$

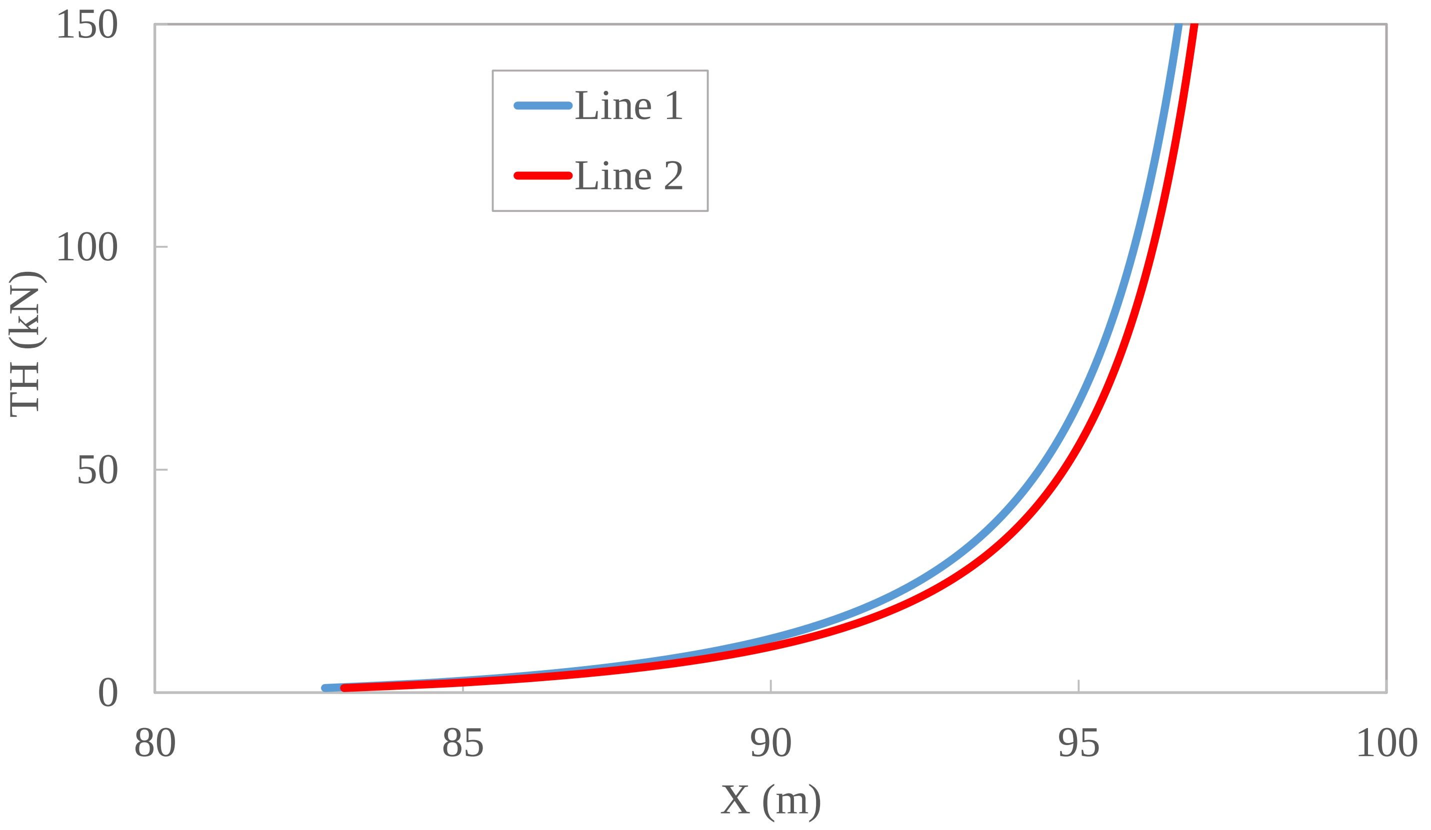


Floatings & Moorings

$$a = {}^{T_H}/_{\omega}$$

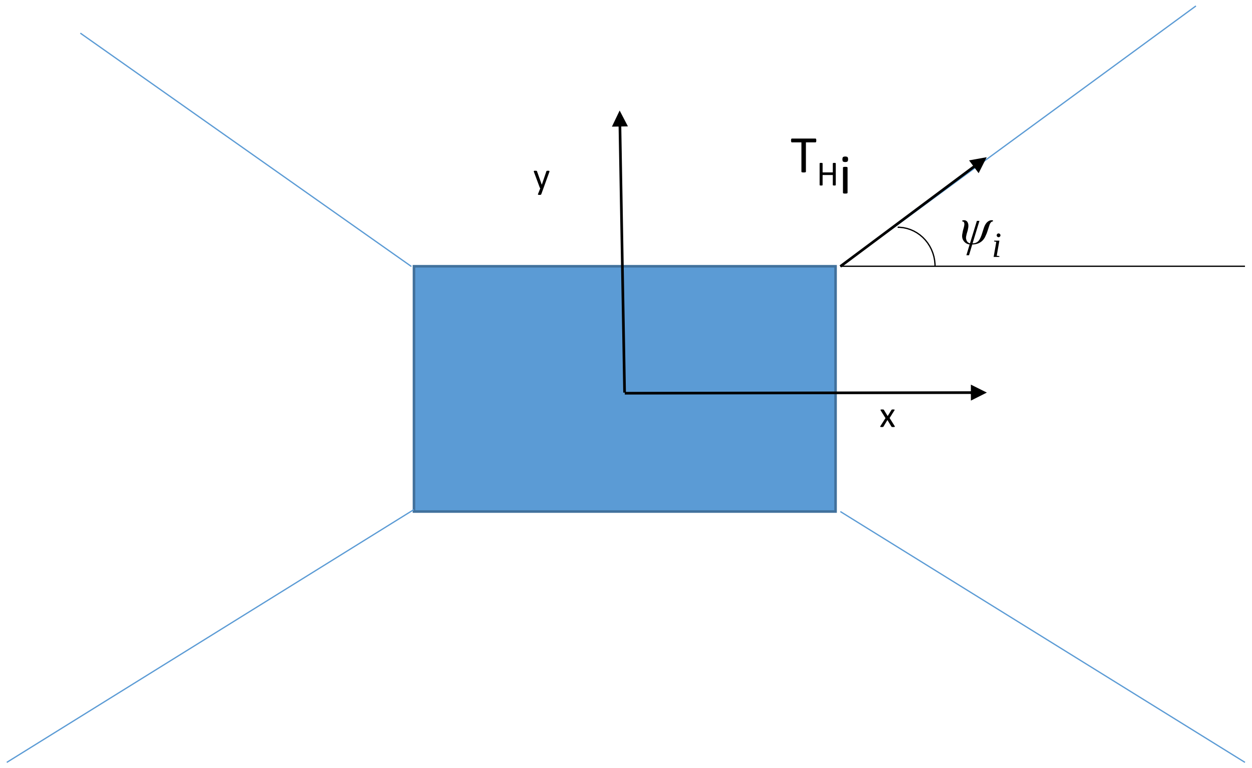
$$X = l - h\left(1 + 2\frac{a}{h}\right)^{\frac{1}{2}} + a\cosh^{-1}\left(1 + \frac{h}{a}\right)$$

- Line 1, ω=850 N·m^{-1}, h=20 m and l=100 m.
- Line 2, ω=1000 N·m^{-1}, h=20 m and l=100 m.



Floatings & Moorings

Spread mooring approach:



The equations shown before can be generalized for a multiple line problem with the proper implementation.

$$F_x = T_{Hi}\cos\Psi_i$$

$$F_y = T_{Hi}\sin\Psi_i$$

Floatings & Moorings

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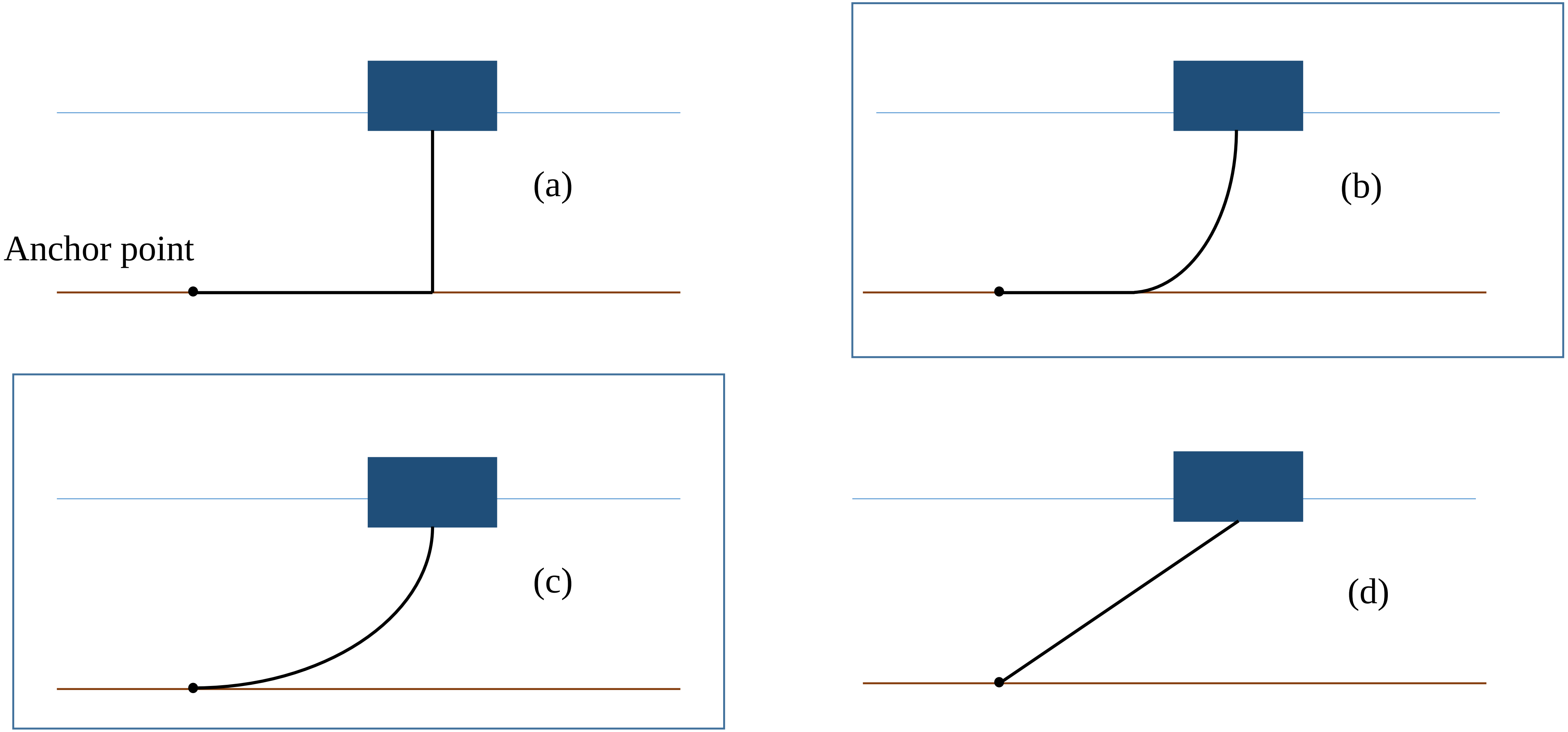
Normal conditions are already covered but there are two different states that are not solved yet



Floatings & Moorings

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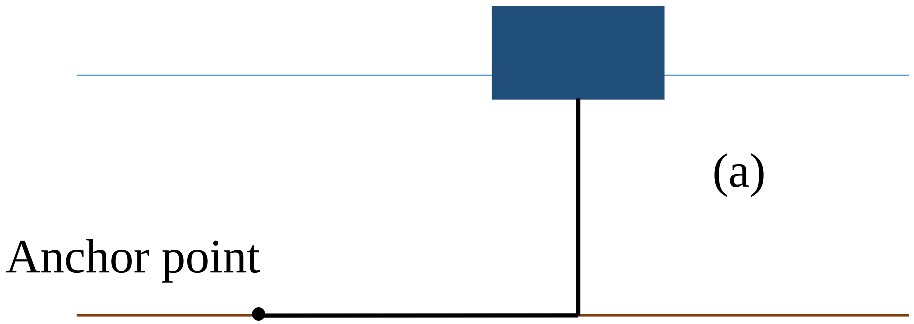
Normal conditions are already covered but there are two different states that are not solved yet



$$T_z \cong \omega h g$$

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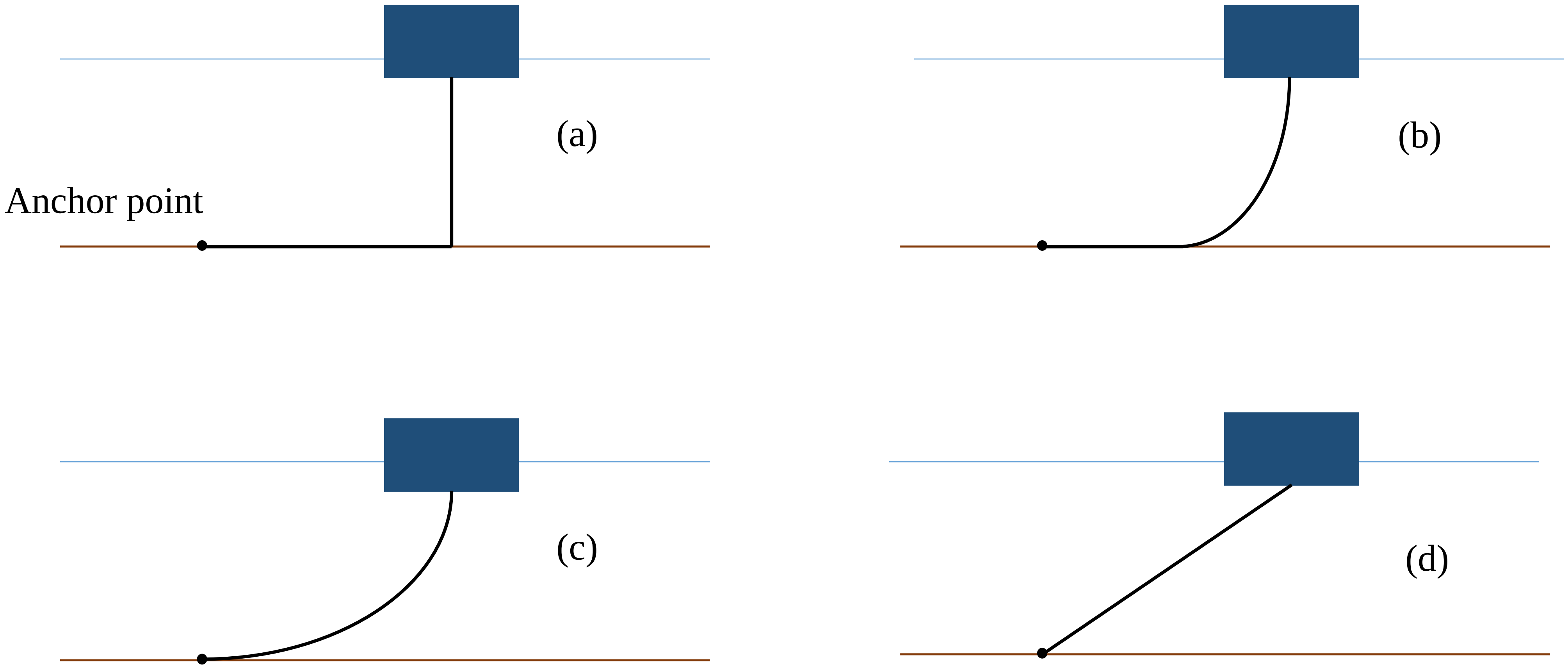
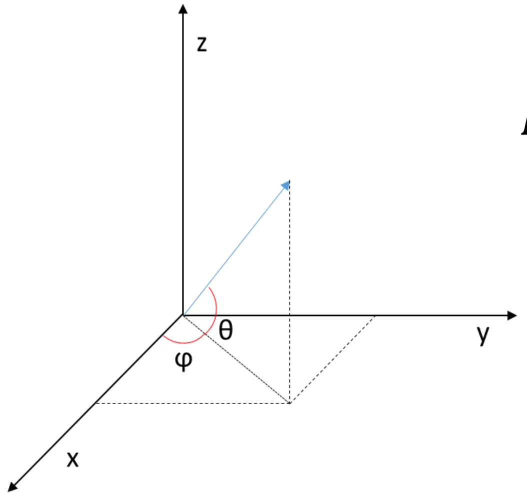
Normal conditions are already covered but there are two different states that are not solved yet



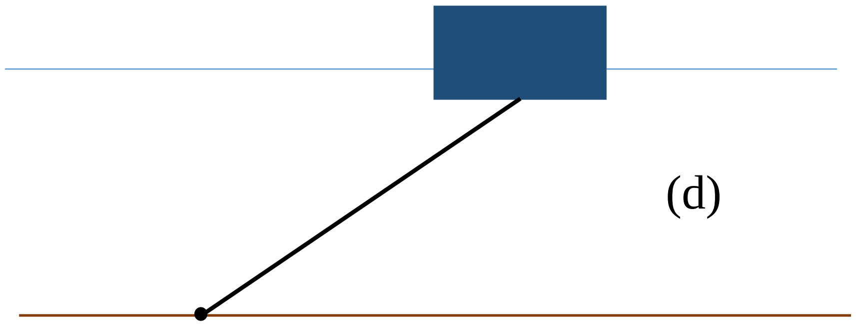
Floatings & Moorings

Normal conditions are already covered but there are two different states that are not solved yet



$$\boldsymbol{F}_T = \boldsymbol{F}_1 + \boldsymbol{F}_2 + \boldsymbol{F}_3 + \boldsymbol{F}_4 \cdots$$
$$F_{Tx} = F_T \cdot \cos\theta_T \cdot \cos\varphi_T$$
$$F_{Ty} = F_T \cdot \cos\theta_T \cdot \sin\varphi_T$$
$$F_{Tz} = F_T \cdot \sin\theta_T$$

$$Force\ for\ i\ mooring \begin{cases} F_{ix} = \dfrac{F_{Tx} \cdot \cos\varphi_i}{\sum_j^n \cos\varphi_j} \\ F_{iy} = \dfrac{F_{Ty} \cdot \sin\varphi_i}{\sum_j^n \sin\varphi_j} \\ F_{iz} = \dfrac{F_{Tz} \cdot \sin\theta_i}{\sum_j^n \sin\theta_j} \end{cases}$$



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Floatings & Moorings

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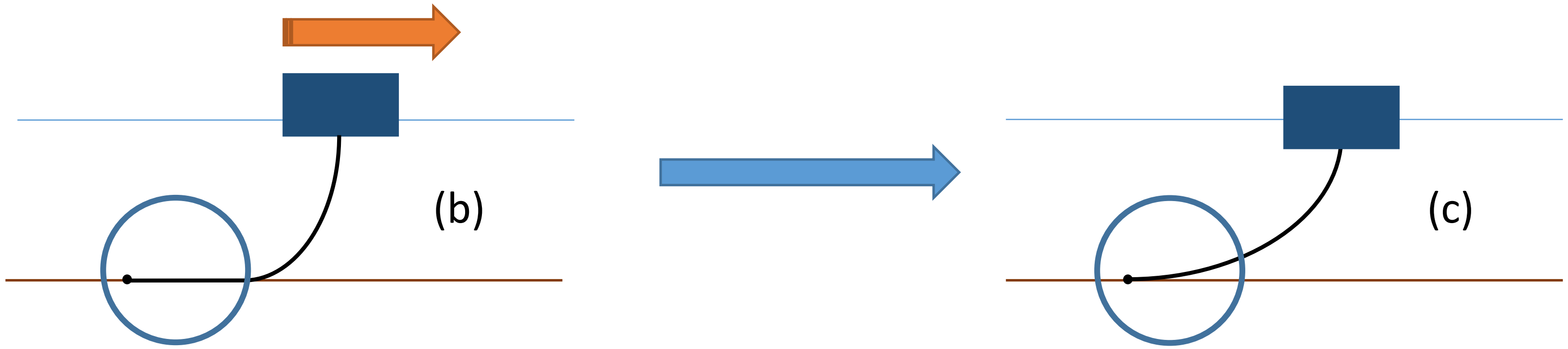
One line validation I

Johanning (2007), Laboratory dimensions.



Floatings & Moorings

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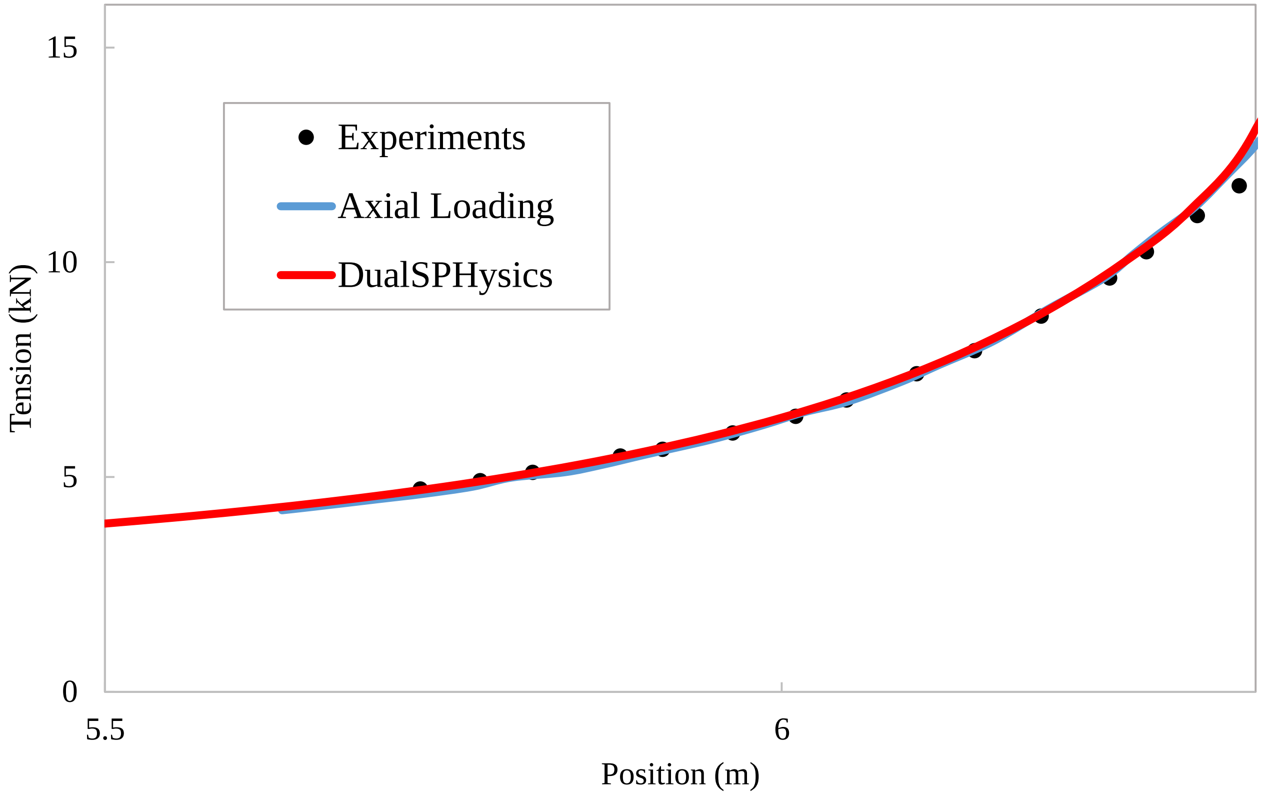
One line validation I

Johanning (2007), Laboratory dimensions.

Parameter	Value
h	2.651 m
ω	1.036 $N \cdot m^{-1}$
l	6.98 m
Minimum extension	5.735 m
Maximum extension	6.367 m



Floatings & Moorings

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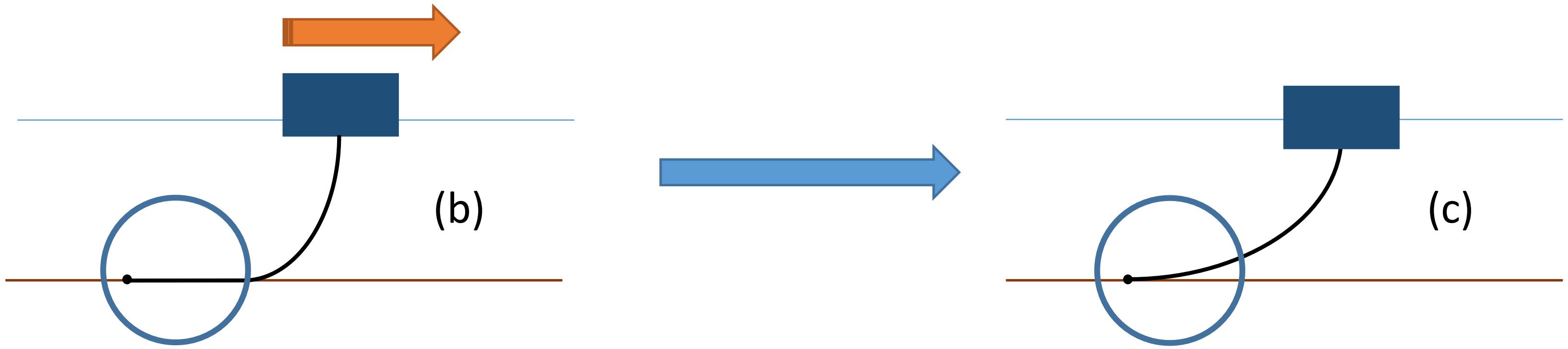
One line validation II

Johanning (2006), Real dimensions.



Floatings & Moorings

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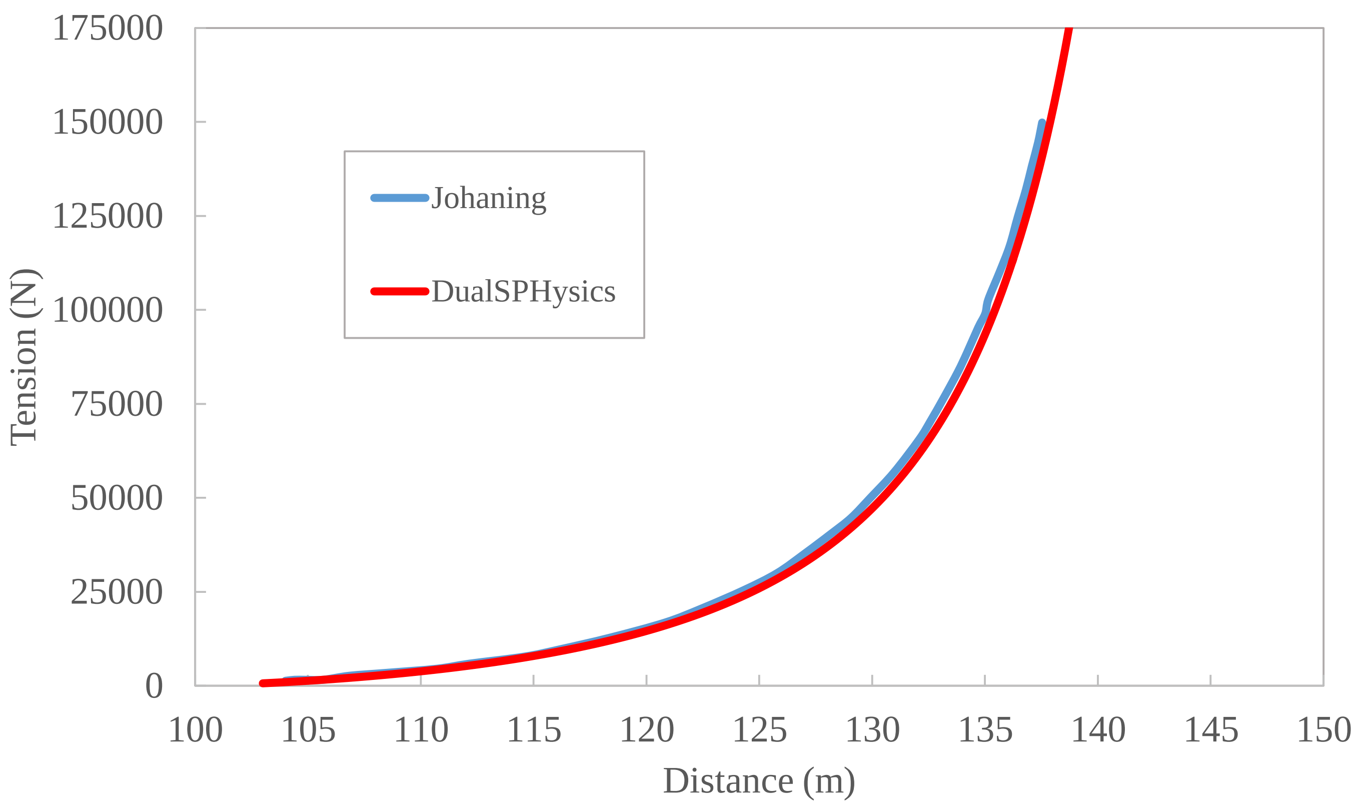
One line validation II

Johanning (2006), Real dimensions.

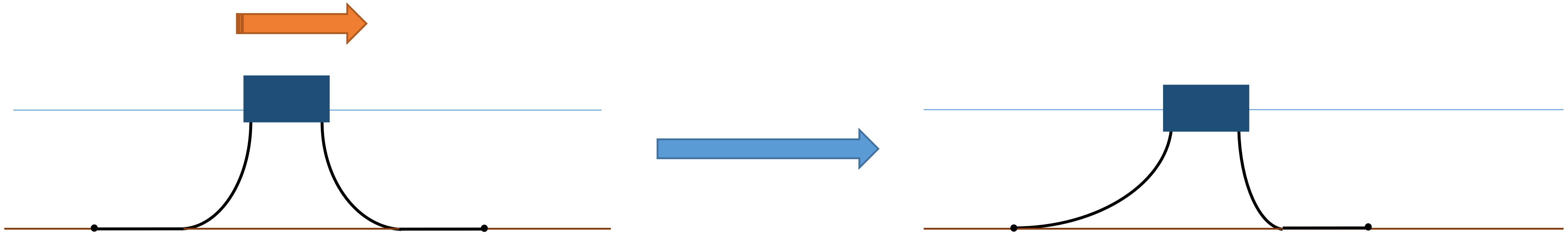
Parameter	Value
h	50 m
ω	918.75 N·m^{-1}
l	150 m
Minimum extension	102 m
Maximum extension	140 m



Floatings & Moorings

Multiple line validation

Johanning (2006), Real dimensions.



Floatings & Moorings

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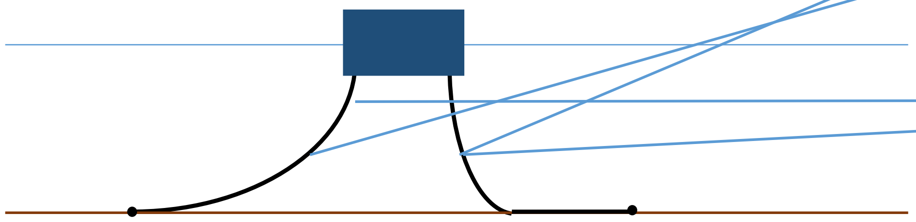
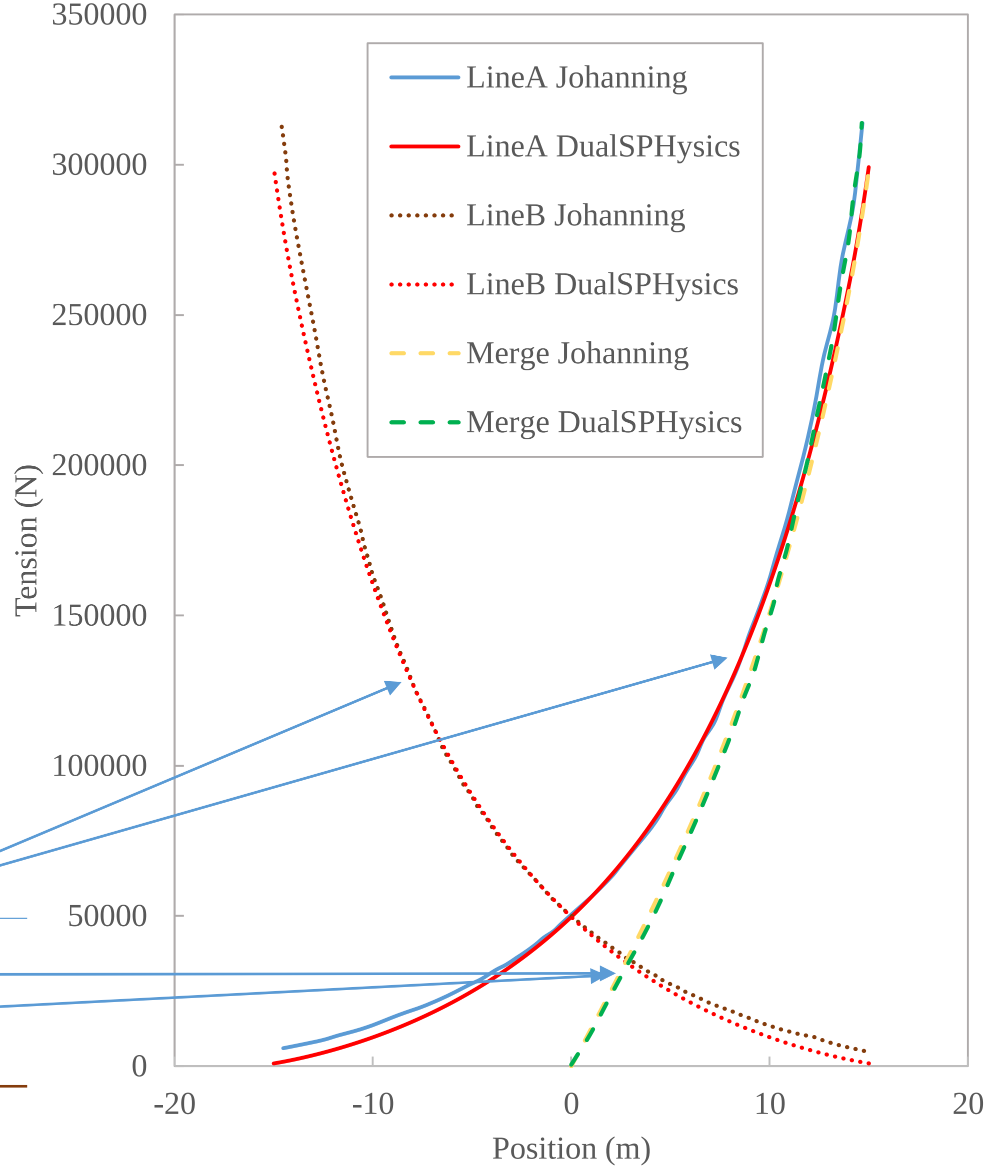
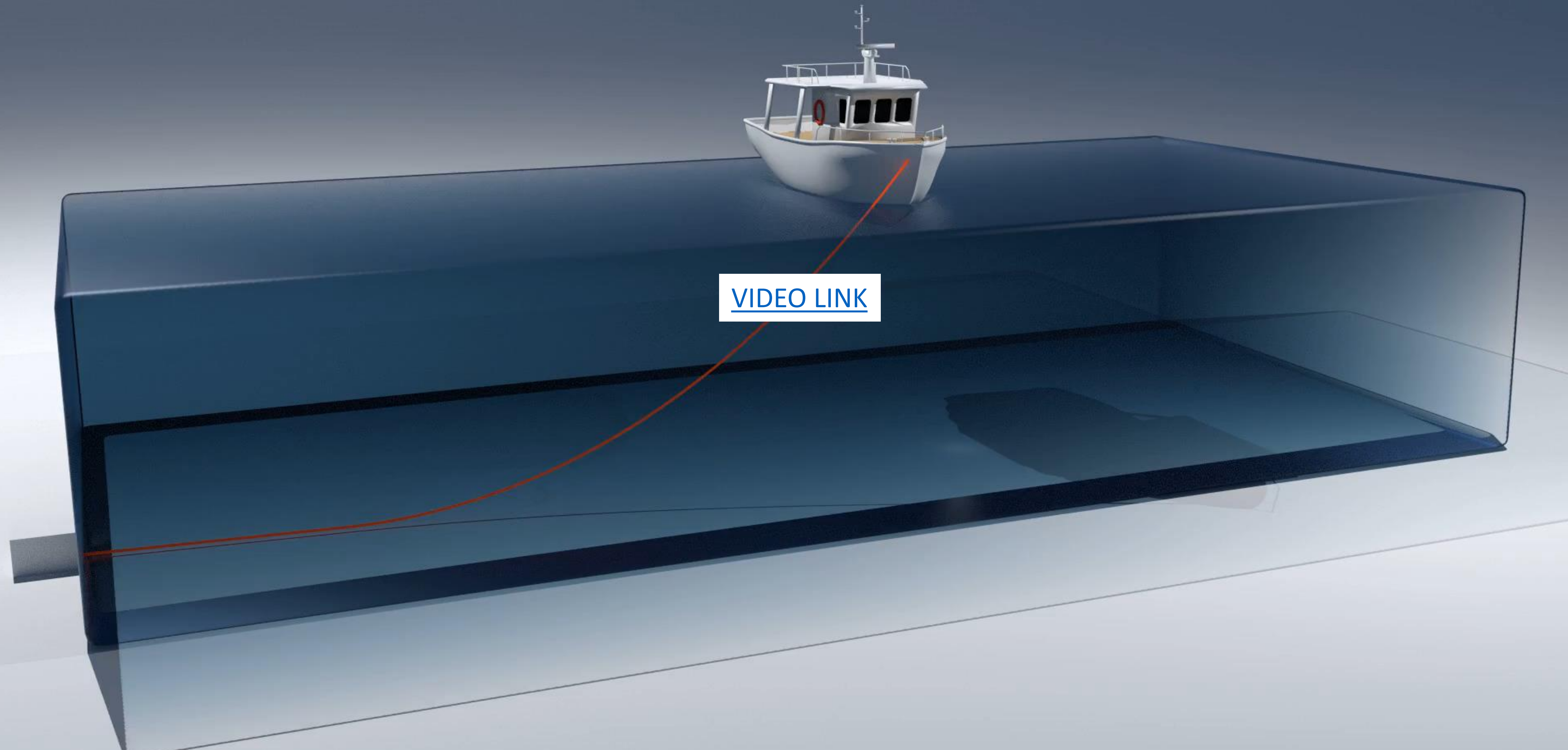
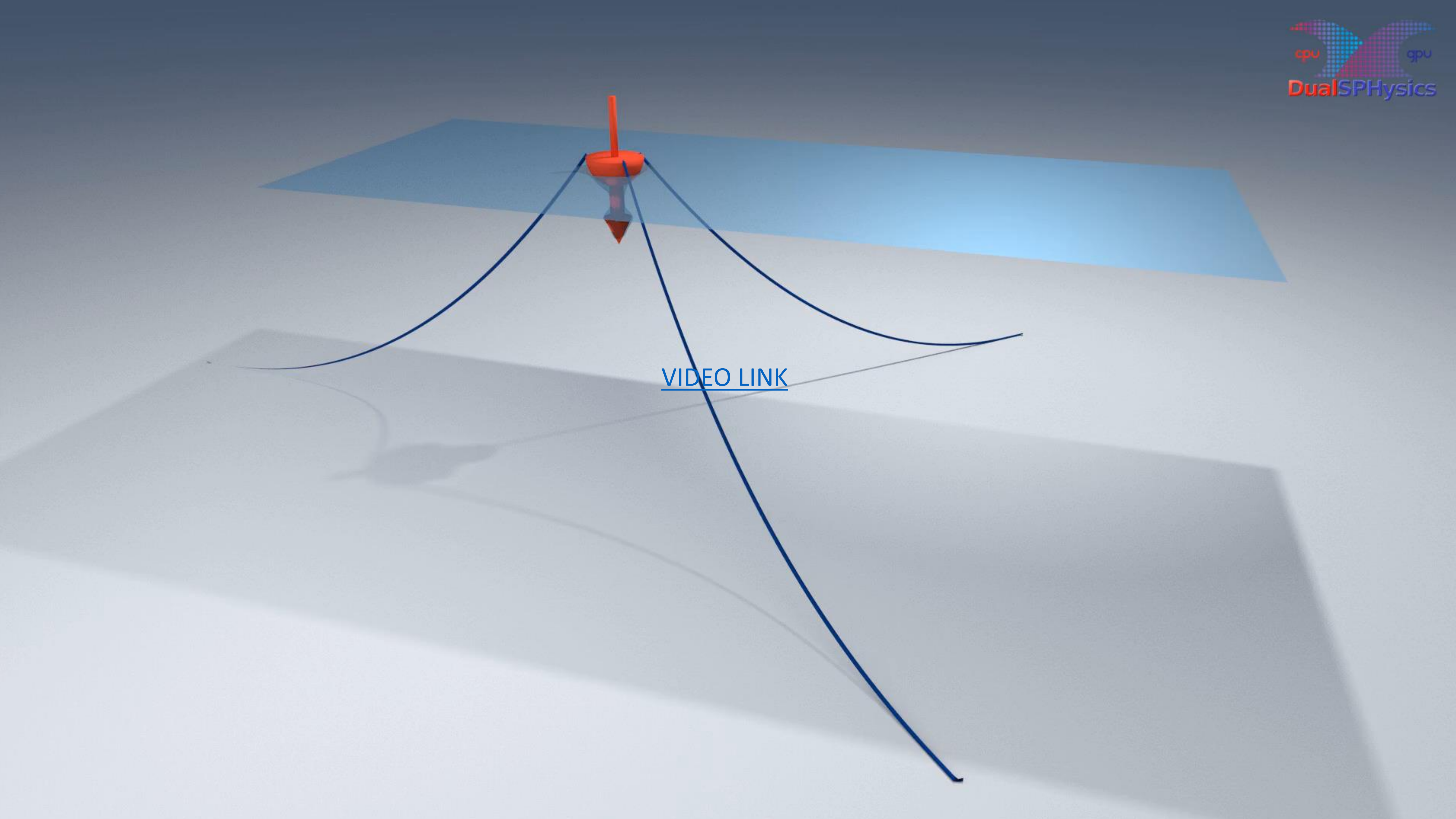
Multiple line validation

Parameter	Value
h	50 m
T_{H0}	50 kN
l	75 m
Minimum extension from resting point	-15 m
Maximum extension from resting point	15 m






VIDEO LINK


VIDEO LINK

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Conclusions

-Moorings & Floating bodies

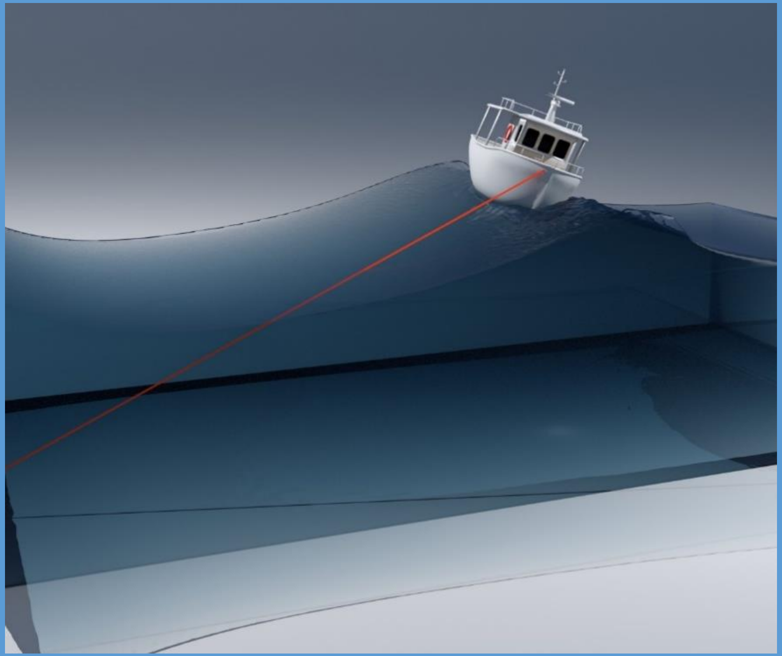
The functionalities necessary to simulate moorings were implemented in DualSPHysics. The **new implementation** is able to **solve** properly both **chain forces** and the effect moorings in the floating bodies.

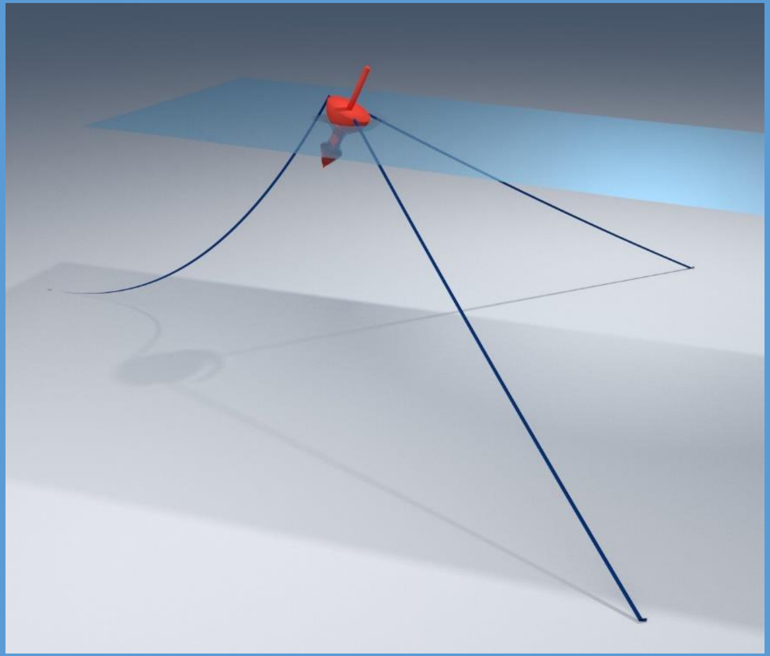
The **buoyancy** of the floating bodies was **validated** against **numerical data** from VOF showing a really good agreement.

The implementation of **moorings** was **validated** against **experimental** data and compared with other **numerical models**. This validation provided really good agreement with both numerical and experimental data at various scales.

Two application **examples** were presented, the first one is a **boat** under the action of side waves and only **one moored line**. The second application consisted of a **wind-turbine base** with **three moorings** under the effect of extreme waves.

Mooring implementation in SPH models





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