Numerical Analyses and Sensitivity Studies for Development of the Pendulous Method

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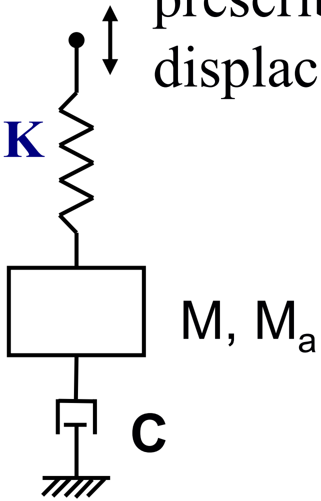
Challenge of deployment in increasing WD (250 Te payload, 2000-3000 m WD)

- Disadvantage of wire rope: self weight + axial resonance (DAF)
- Synthetic fiber rope → issues to be solved: bending and heating + axial resonance (w/o heave compensation)

The Pendulous Method



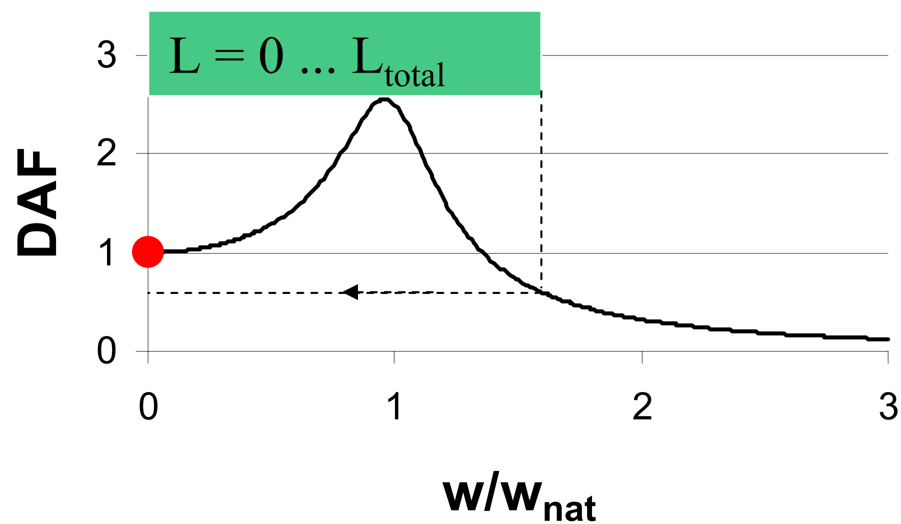
prescribed vertical displacement (X_o)

$$K = \frac{(EA)_{equiv}}{L}$$

$$T_{nat} = \frac{2\pi}{\sqrt{\dfrac{K}{M + M_a + \dfrac{m}{e}}}} = \frac{2\pi}{w_{nat}}$$

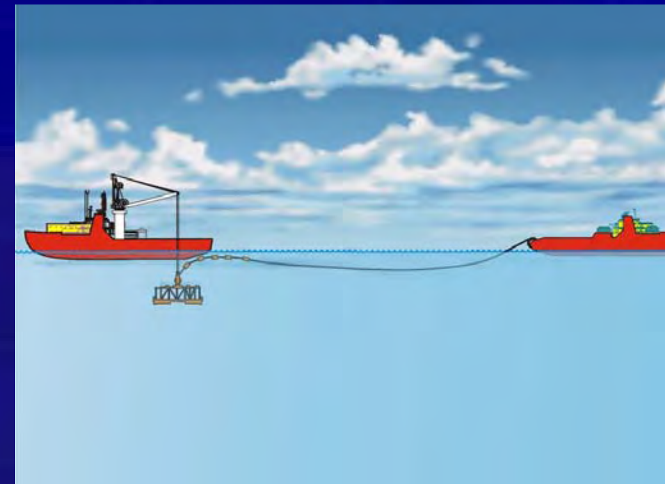
frequency ratio β

$$\frac{w}{w_{nat}} = f(L_{deployed})$$

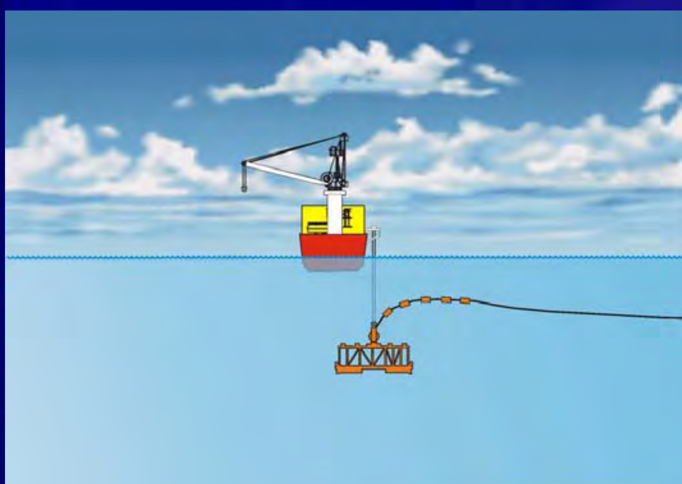


The Pendulous Method

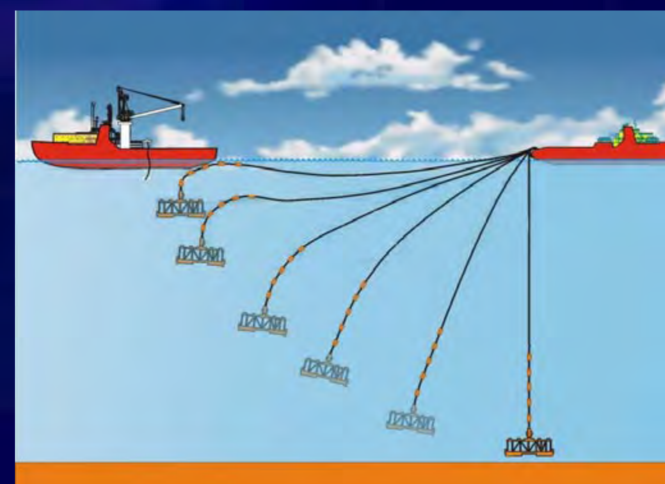
Transportation vessel



Overboarding



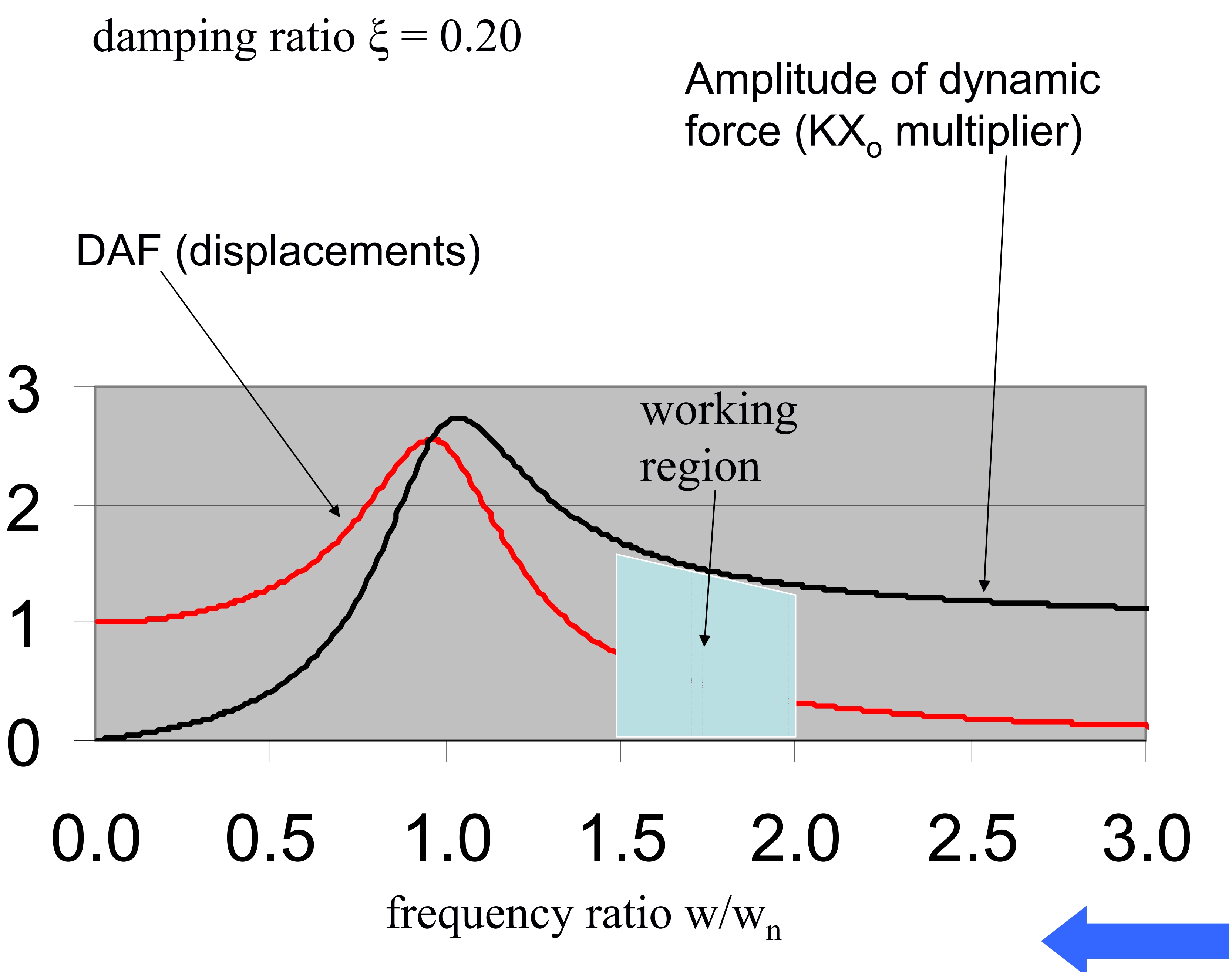
Hangoff



Pendulous Motion

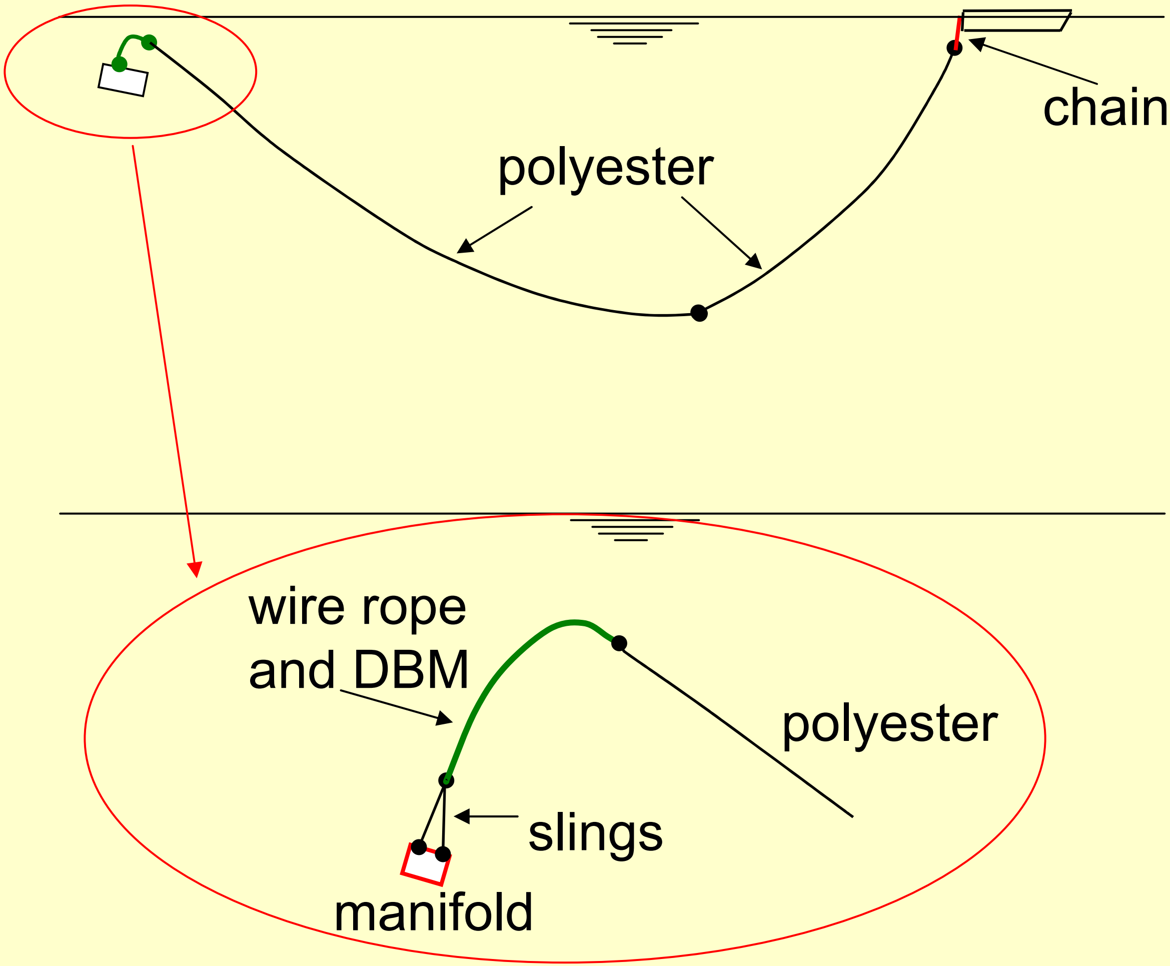
The Pendulous Method (cont.)

- Conceived to overcome the above constraints (DAF1)
- Utilization of the Pendulous Motion
- Utilization of two workboats
- Distance between vessels 90% of cable length
- Installation cable, from subsea hardware: wire rope with DBM, polyester and chain
- Due to drag the pendulous motion will be very slow


damping ratio ξ = 0.20
Amplitude of dynamic force (KX$_o$ multiplier)
DAF (displacements)
working region
3
2
1
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
frequency ratio w/w$_n$

General system configuration

(side view, just after release)



System components

material	MBL (Te)	Diam. (mm)	length (m)	mass (kg/m)	wet wgt (kgf/m)	EA (MN)
chain R4	1097	105	30	222.7	193.8	840
polyester	1250	210	1600	29	7.40	300
wire rope	1000	127	60	57.8	44.7	965

Weight in air: 280 Te

WD: 1900m

Dimensions: 16.6 x 8.5 x 5.1 m (L x B X H)

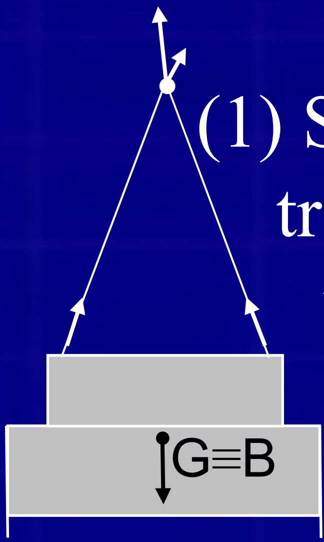
CG 3.15 m above base line (CG≡CB)

Physics of the problem

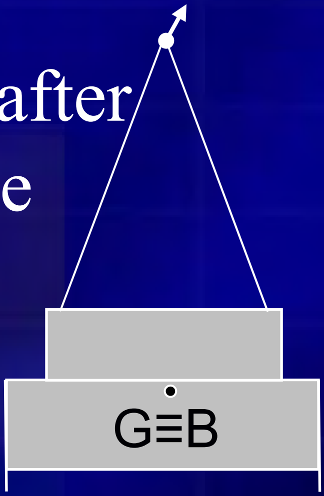
- Equipment of complex topology
- Volume of the envelope dimensions: 728 m^3
- Steel volume: 35.7 m^3 (< 5% total volume)
- Some assumptions are needed in order to simplify the computer model
- 1st aproach to concentrate drag and added mass at CG ➔ inadequate
- improvement ➔ center of pressure and spatial distribution of drag and lift forces

Physics of the problem (cont.)

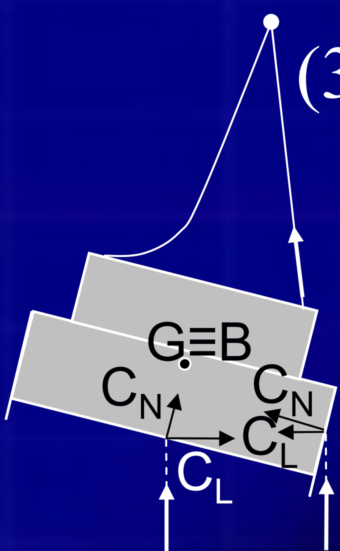
(1) Suspended at transportation vessel side



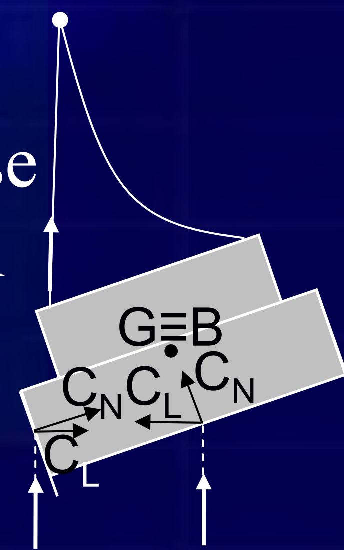
(2) Just after release



(3) Clockwise rotation



(4) Anti-clockwise rotation



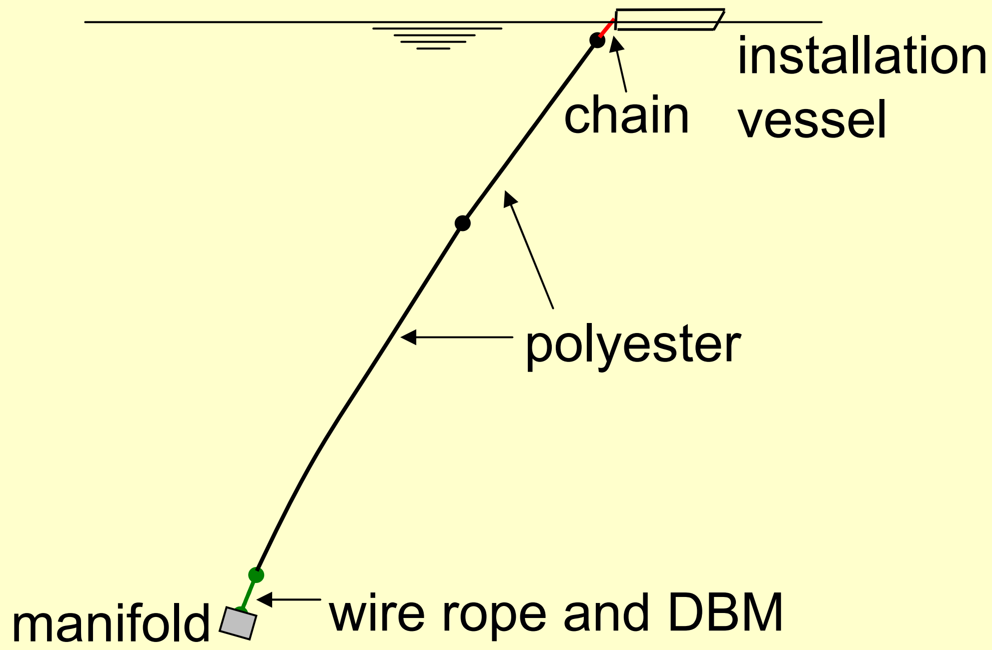
Development of the concept

- Conceived in 2003, based on the procedure for installation of torpedo pile
- Numerical analyses with Orcaflex to demonstrate the feasibility – parametric study of main variables
- Model tests at LabOceano (UFRJ) in 2004
- 1:1 scale prototype test in December 2005

Some results of numerical analysis

- Three distinct phases:
  - equipment hung off at side of transportation vessel
  - pendulous motion
  - equipment supported by installation vessel

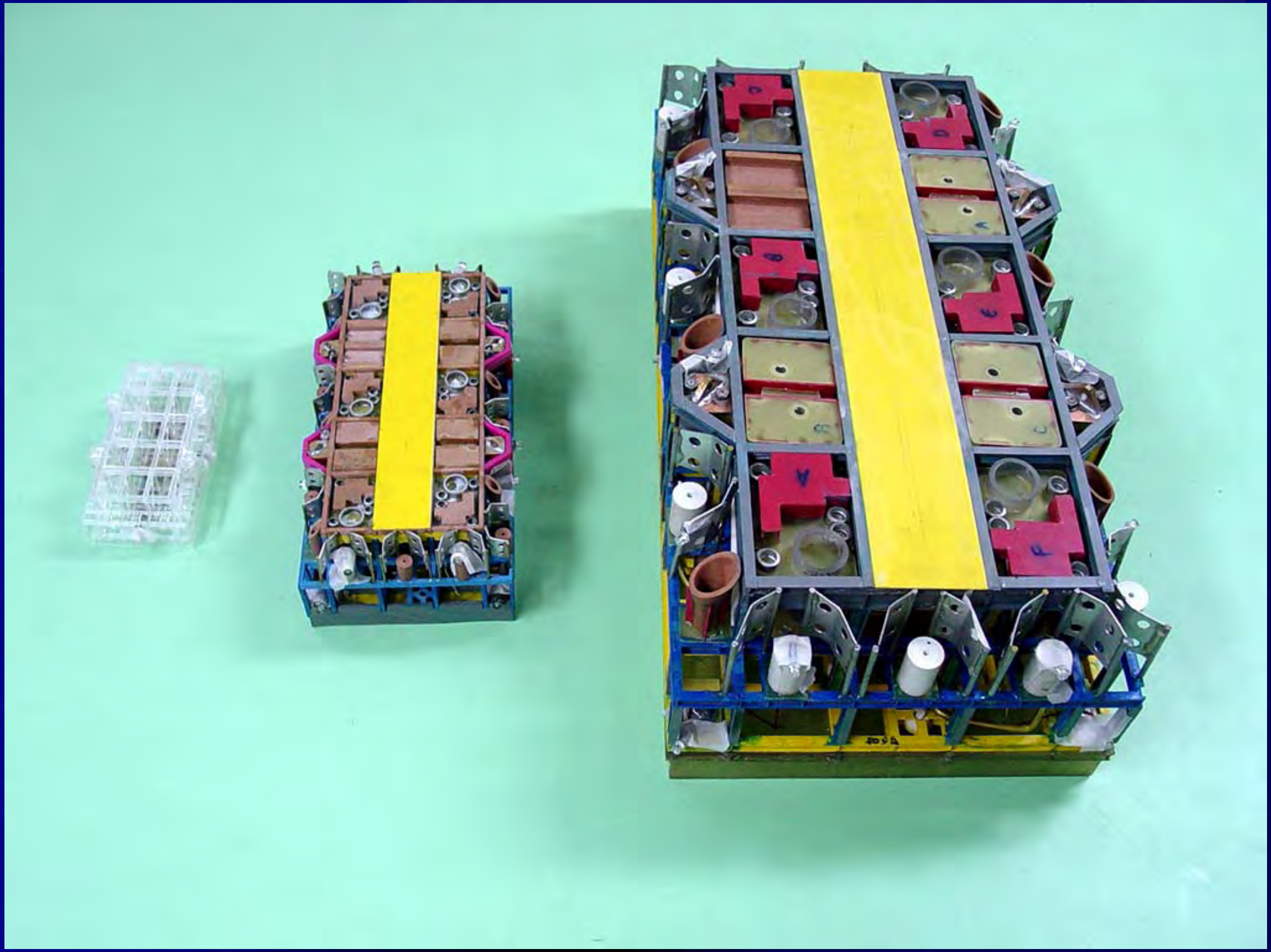
Configuration 10 minutes after release



1000_sec.avi   60_sec.avi

Model tests

- Model tests at 1:35, 1:70 and 1:130 scales for manifold #2 – excessive rotations detected in some cases

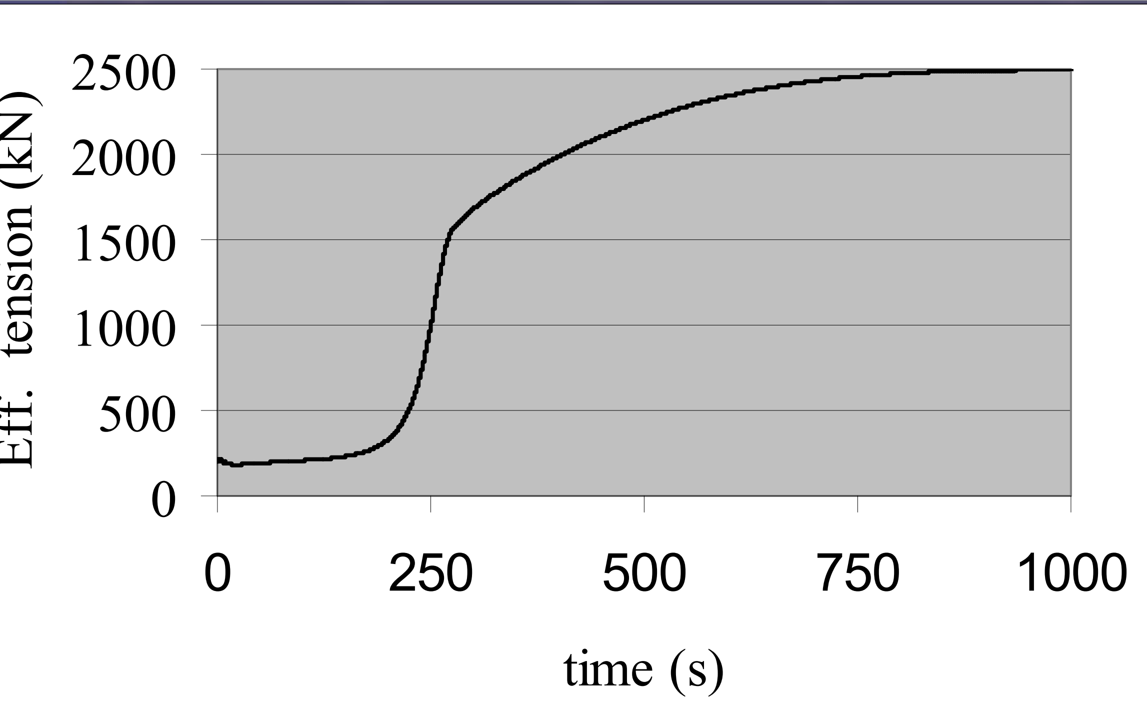


Model test

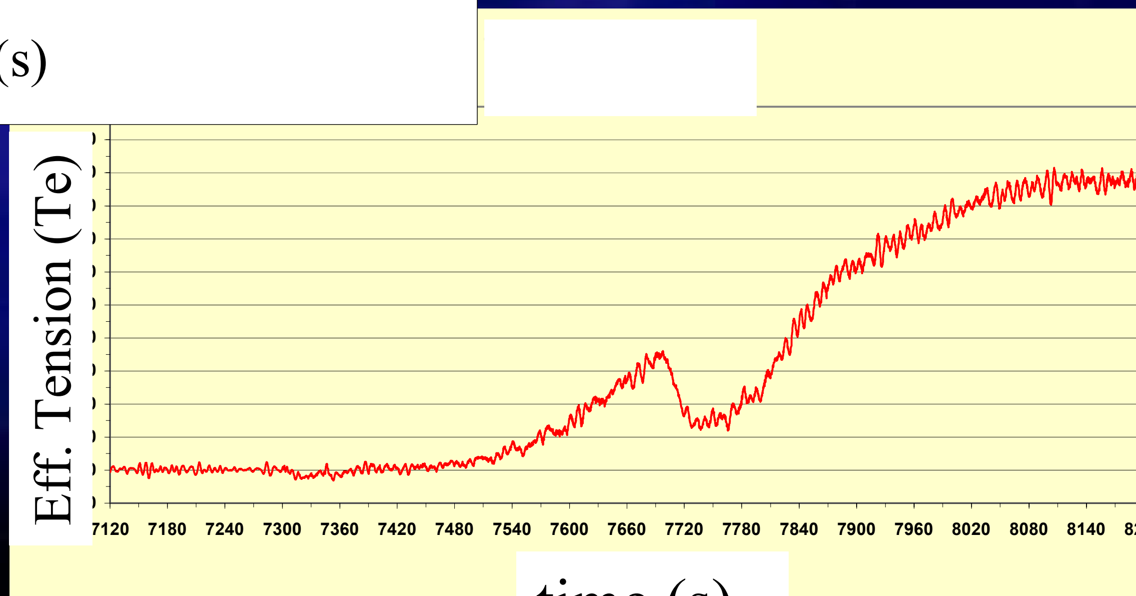
1:1 Prototype test

- Decision to build and install a 1:1 prototype for qualification of the method and installation procedur

Cable effective tension, installation vessel side



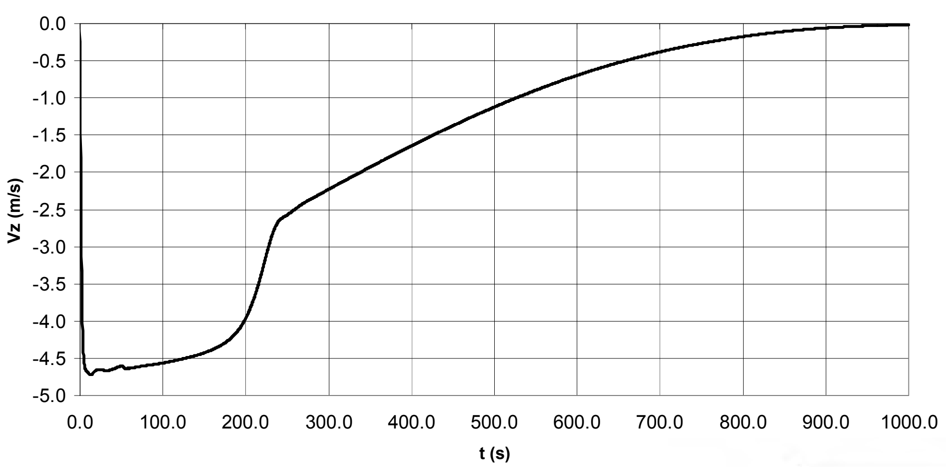
numerical analysis



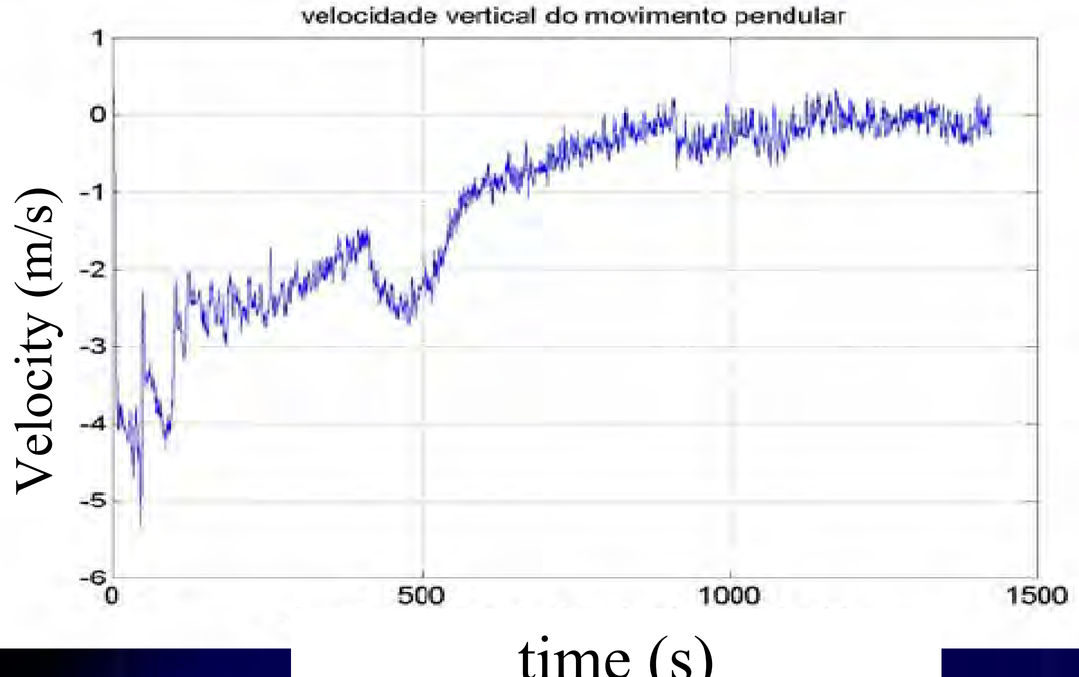
measurements

Manifold vertical velocity

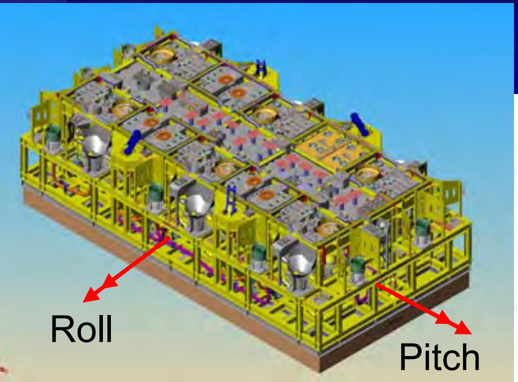
numerical analysis

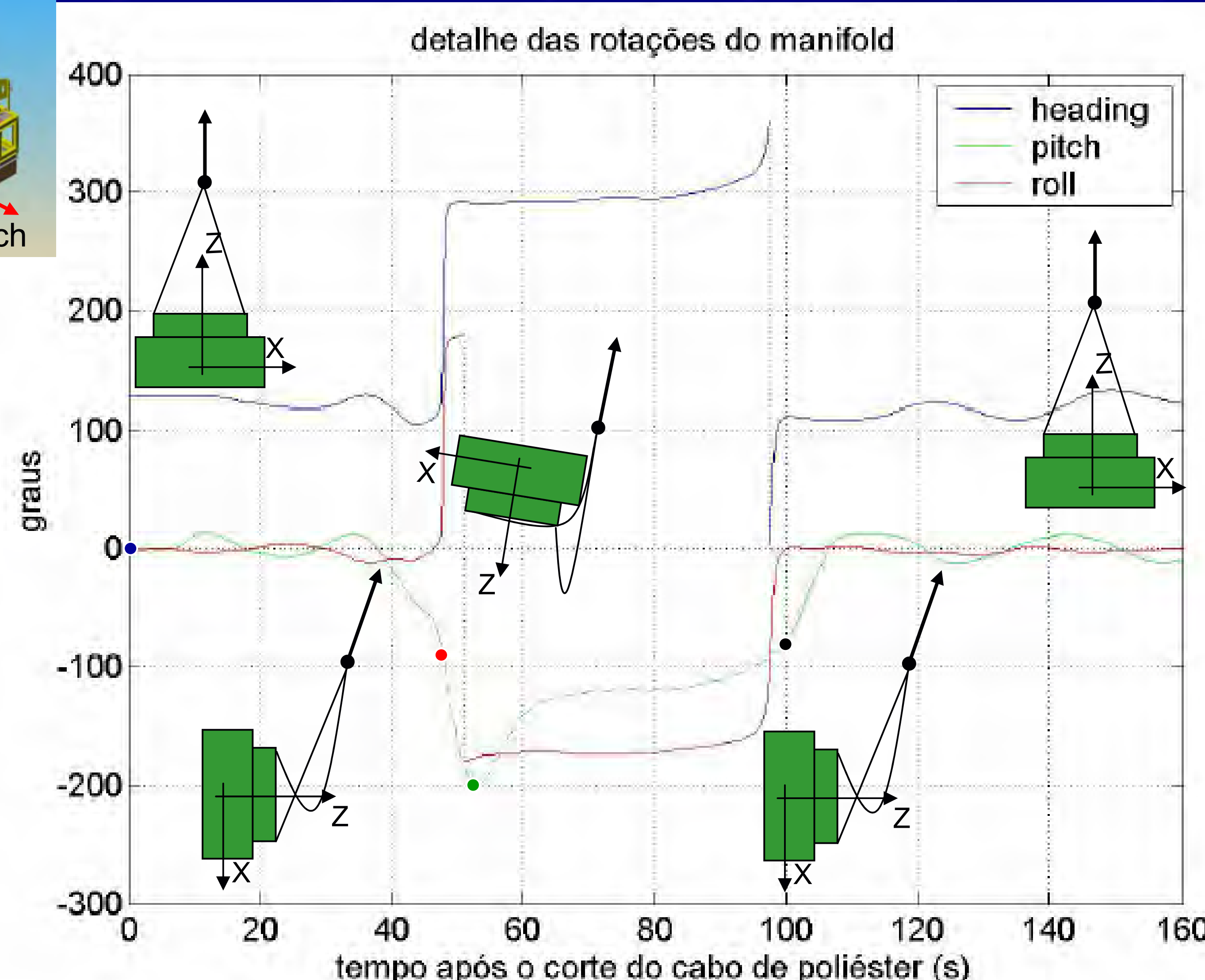


measurements



Rotations


Roll
Pitch


detalhe das rotações do manifold
heading
pitch
roll
graus
tempo após o corte do cabo de poliéster (s)
400
300
200
100
0
-100
-200
-300
0
20
40
60
80
100
120
140
160
Z
X

Excessive rotations and mitigation

- Identification of excessive rotations
- Mitigation
  - improvement of hydrodynamic stability
    - ✓ a more adequate equipment geometry, e.g., near vertical (slightly slanted) panels around it
    - ✓ lowering of CG, e.g., additional weight at the equipment bottom or additional buoyancy at top
  - increase of sling reaction forces at beginning
    - ✓ additional buoyancy to the distributed buoyancy modules
    - ✓ counterweight and wire rope

Conclusions

- Feasibility of the Pendulous Installation Method
  - •Good comparison between numerical analysis x model tests x full scale test
  - •Axial loads increase monotonically
  - •No swing back and forth, due to damping
  - •Attenuation of axial force, prevents resonance
- Control of rotations at beginning
  - •counterweight + wire rope (MSGL 2&3)
  - •improvement of hardware geometry (future)


27 12 2005