INSTALLATION OF DEEPWATER MANIFOLDS BY THE PENDULOUS METHOD UNDER THE LIGHT OF DEEP OCEAN BASIN MODEL TESTING AND NUMERICAL

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Dimensional Analysis

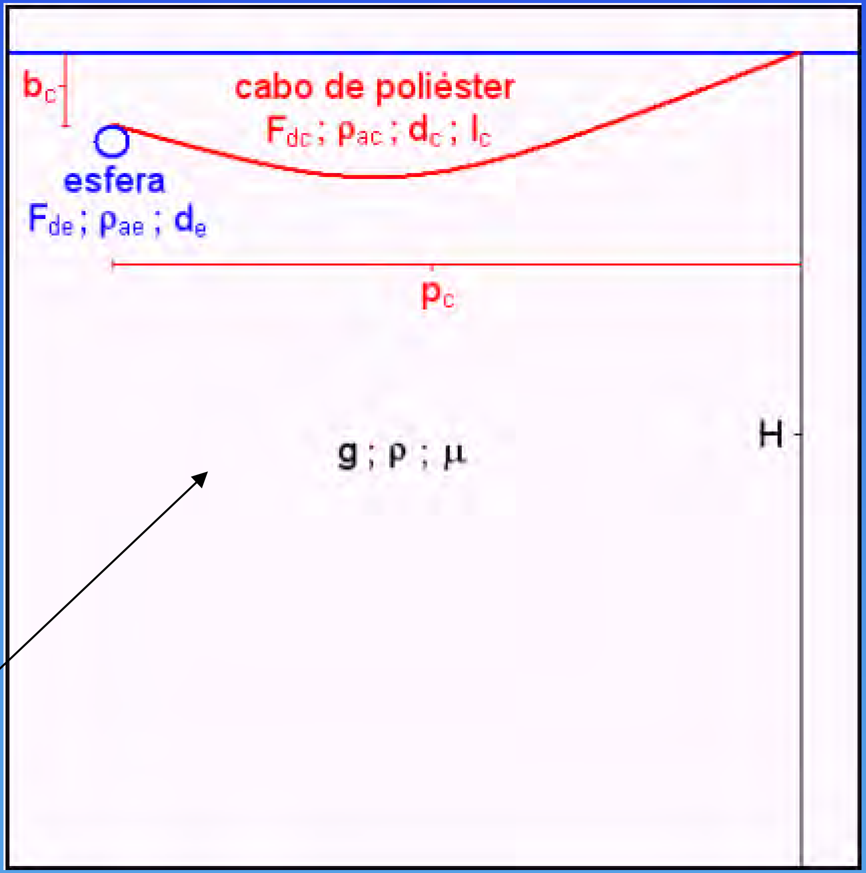
- Essential for planning
- Find non-dimensional numbers for properties comparisons and extrapolation
- Create a physically significant basis for the UNEXPECTED BEHAVIOR (HUSE's LAW)

Dimensional Analysis for a non conventional operation as is the case of the PIM

First:
simplified
with sphere

Second:
Complete case
with
manifold
and sling

Variables of
interest



(Buckingham's Pi Theorem)

$$U_e(t) = f\,(g;\ \rho;\ \mu;\ F_{de};\ \rho_{ae};\ d_e;\ F_{dc};\ \rho_{ac};\ d_c;\ l_c;\ p_c;\ b_c)$$

$$u_c(s,t) = f\,(U_e(t))\ [m/s]$$

n=13

k=3

U_e	g	ρ	μ	F_{de}	ρ_{ae}	d_e
$[L\ T^{-1}]$	$[L\ T^{-2}]$	$[M\ L^{-3}]$	$[M\ L^{-1}\ T^{-1}]$	$[M\ L\ T^{-2}]$	$[M\ L^{-3}]$	$[L]$

F_{dc}	ρ_{ac}	d_c	l_c	p_c	b_c
$[M\ L\ T^{-2}]$	$[M\ L^{-3}]$	$[L]$	$[L]$	$[L]$	$[L]$

n-k = 10

REARRANGING

(Buckingham's Pi Theorem)

ADIMENSIONAIS	Π_1	Π_2	Π_3	Π_4	Π_5
	Fr_e	Re_e	C_{de}	$\frac{\rho_{ae}}{\rho}$	C_{dc}
	Π_6	Π_7	Π_8	Π_9	Π_{10}
	$\frac{\rho_{ac}}{\rho}$	$\frac{d_c}{d_e}$	$\frac{l_c}{d_e}$	$\frac{p_c}{d_e}$	$\frac{b_c}{d_e}$

(Buckingham’s Pi Theorem)

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Geometric parameters

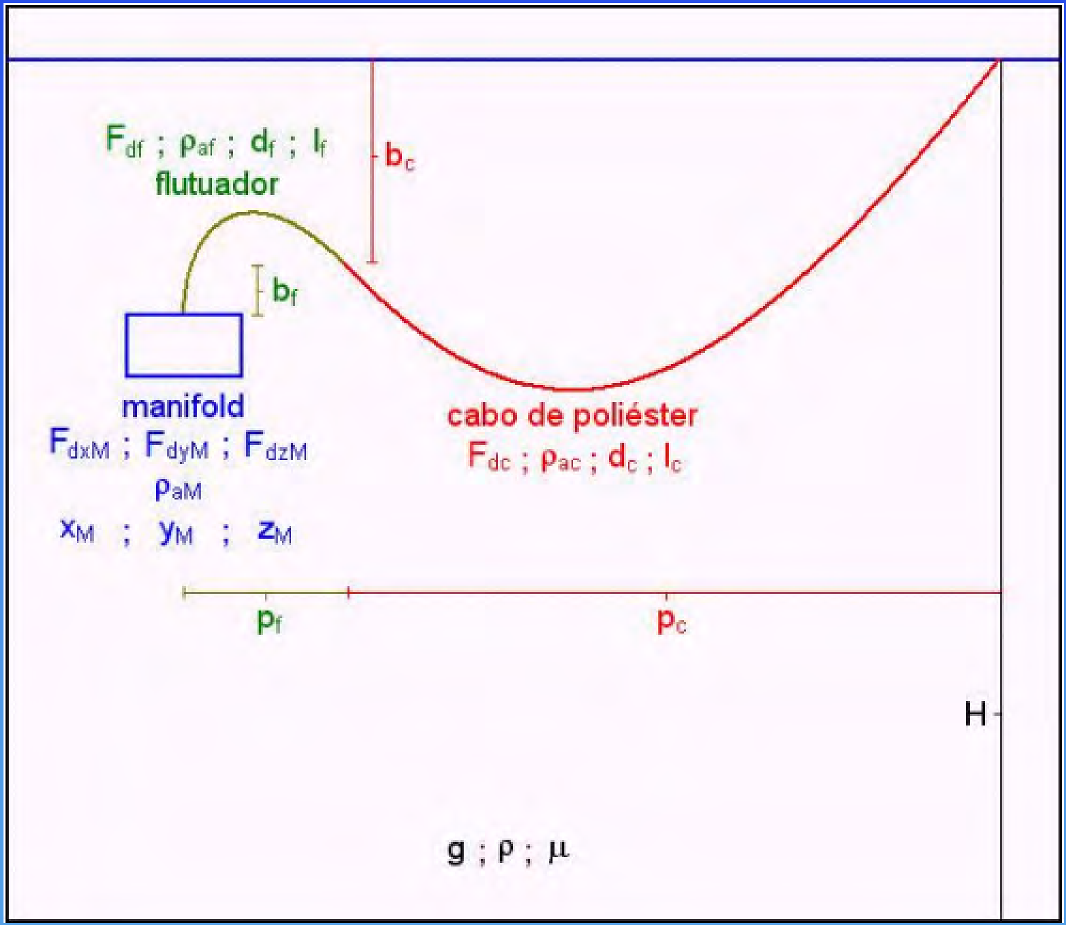
(Buckingham's Pi Theorem)

ADIMENSIONAIS	Π_1	Π_2	Π_3	Π_4	Π_5
	Fr_e	Re_e	C_{de}	$\dfrac{\rho_{ae}}{\rho}$	C_{dc}
	Π_6	Π_7	Π_8	Π_9	Π_{10}
	$\dfrac{\rho_{ac}}{\rho}$	$\dfrac{d_c}{d_e}$	$\dfrac{l_c}{d_e}$	$\dfrac{p_c}{d_e}$	$\dfrac{b_c}{d_e}$

Mass ratios for cable and sphere

$$\frac{P_c * E_c}{E_c} = \frac{Vol_c * (\rho_c - \rho)}{Vol_c * \rho} = \frac{(\rho_c - \rho)}{\rho} = \frac{\rho_{ac}}{\rho}$$

Applying Dimensional Analysis for the Manifold with Floaters and Cable



(Buckingham's Pi Theorem)

$$U_M(t) = f(g;\ \rho;\ \mu;\ F_{dxM};\ F_{dyM};\ F_{dzM};\ \rho_{aM};\ x_M;\ y_M;\ z_M;\ F_{dc};\ \rho_{ac};\ d_c;\ l_c;\ p_c;\ b_c;\ F_{df};\ \rho_{af};\ d_f;\ l_f;\ p_f;\ b_f)$$

n=23

k=3

n-k=20

$$u_c(s,t) = f(U_M(t))\ [m/s]$$

$$u_f(s,t) = f(U_M(t))\ [m/s]$$

(Buckingham's Pi Theorem)

ADIMENSIONAIS					
	Π_1	Π_2	Π_3	Π_4	Π_5
	$\frac{U^2}{l_c * g}$	$\frac{\mu^2}{\rho^2 * l_c^3 * g}$	C_{dxM}	C_{dyM}	C_{dzM}
	Π_6	Π_7	Π_8	Π_9	Π_{10}
	$\frac{\rho_{aM}}{\rho}$	$\frac{x_M}{l_c}$	$\frac{y_M}{l_c}$	$\frac{z_M}{l_c}$	C_{dc}
	Π_{11}	Π_{12}	Π_{13}	Π_{14}	Π_{15}
	$\frac{\rho_{ac}}{\rho}$	$\frac{d_c}{l_c}$	$\frac{p_c}{l_c}$	$\frac{b_c}{l_c}$	C_{af}
	Π_{16}	Π_{17}	Π_{18}	Π_{19}	Π_{20}
	$\frac{\rho_{af}}{\rho}$	$\frac{d_f}{l_c}$	$\frac{l_f}{l_c}$	$\frac{p_f}{l_c}$	$\frac{b_f}{l_c}$

geometric

(Buckingham's Pi Theorem)

ADIMENSIONAIS					
	Π_1	Π_2	Π_3	Π_4	Π_5
	$\frac{U^2}{l_c * g}$	$\frac{\mu^2}{\rho^2 * l_c^3 * g}$	C_{dxM}	C_{dyM}	C_{dzM}
	Π_6	Π_7	Π_8	Π_9	Π_{10}
	$\frac{\rho_{aM}}{\rho}$	$\frac{x_M}{l_c}$	$\frac{y_M}{l_c}$	$\frac{z_M}{l_c}$	C_{dc}
	Π_{11}	Π_{12}	Π_{13}	Π_{14}	Π_{15}
	$\frac{\rho_{ac}}{\rho}$	$\frac{d_c}{l_c}$	$\frac{p_c}{l_c}$	$\frac{b_c}{l_c}$	C_{df}
	Π_{16}	Π_{17}	Π_{18}	Π_{19}	Π_{20}
	$\frac{\rho_{af}}{\rho}$	$\frac{d_f}{l_c}$	$\frac{l_f}{l_c}$	$\frac{p_f}{l_c}$	$\frac{b_f}{l_c}$

Mass ratios

Possibility for cables and floaters:

diameter distortion to get drag force in Froude scale

- C_{dc}; C_{df}

$$dF_{Dc} = \frac{1}{2} * \rho * U^2 * d_c * Cd_c * ds \qquad U_M = \frac{U_P}{\sqrt{\lambda}}$$

$$\lambda = \frac{l_{cP}}{l_{cM}} \qquad \frac{dF_{DcM}}{dF_{DcP}} = \frac{1}{\lambda^3} = \frac{1}{\lambda} * \frac{d_{cM}}{d_{cP}} * \frac{Cd_{cM}}{Cd_{cP}} * \frac{d_{sM}}{d_{sP}}$$

$$\frac{1}{\lambda^3} = \frac{1}{\lambda} * \frac{d_{cM}}{d_{cP}} * \frac{Cd_{cM}}{Cd_{cP}} * \frac{1}{\lambda} \qquad \frac{1}{\lambda} = \frac{d_{cM}}{d_{cP}} * \frac{Cd_{cM}}{Cd_{cP}}$$

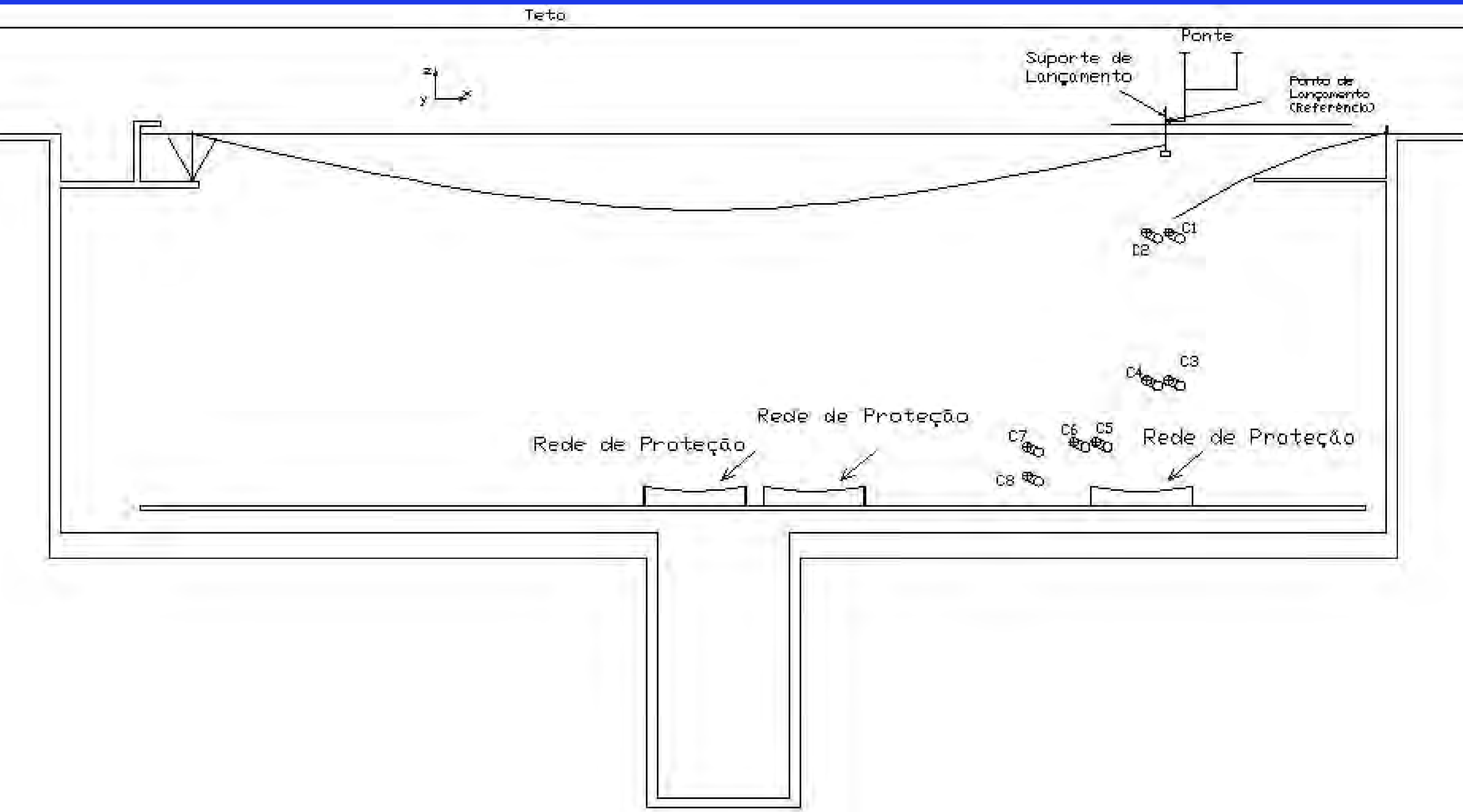
Model test design result

caso	α (º)
Protótipo	44,41
1:35 (Distorcido)	44,34
1:35 (Esc. Linear)	44,36
1:70 (Distorcido)	44,31
1:70 (Esc. Linear)	44,41
1:130 (Distorcido)	44,20
1:130 (Esc. Linear)	44,41

Initial static configuration

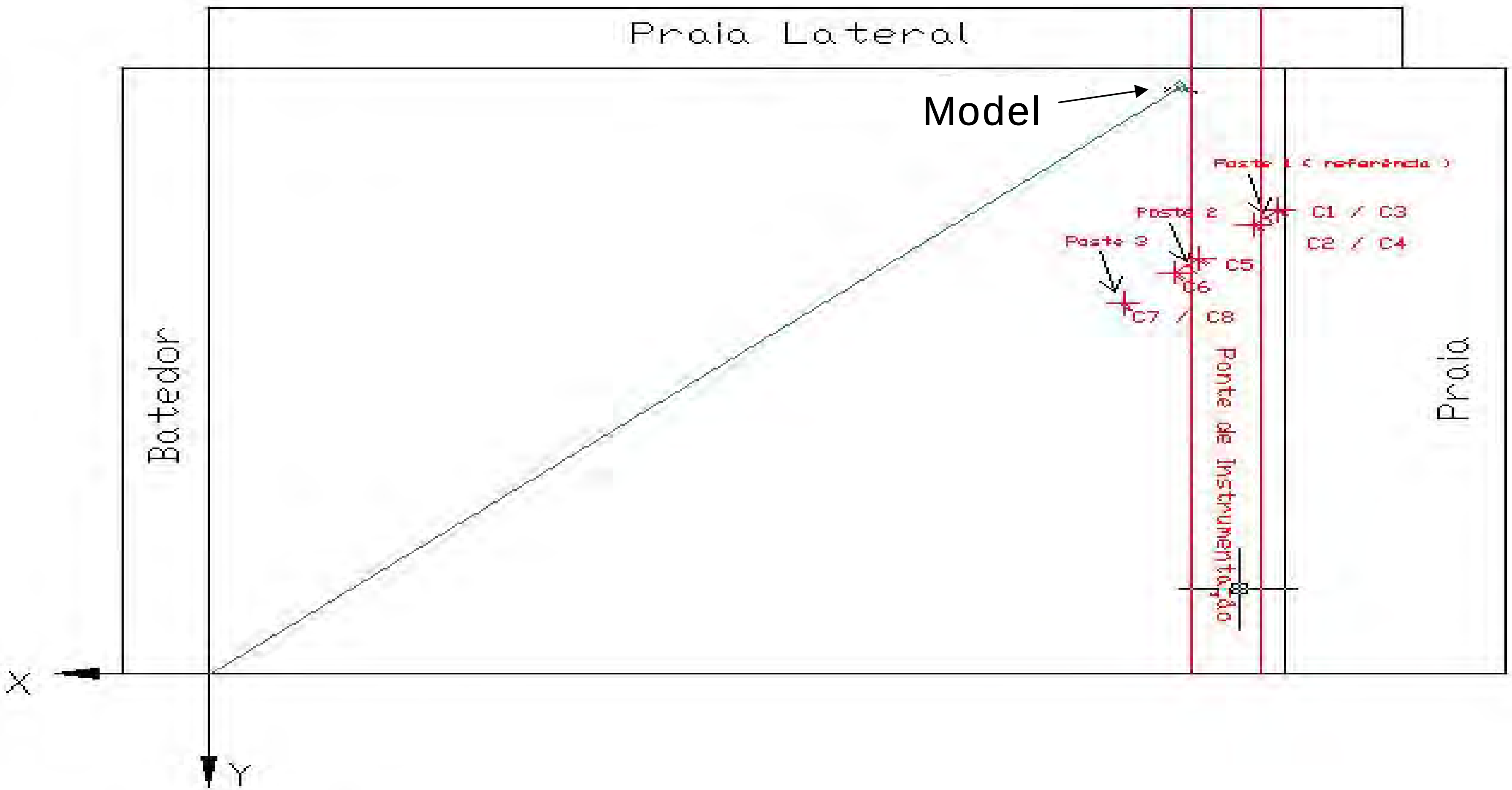
Prototype = linear model linear = distorted x model

Pendulous Lauching

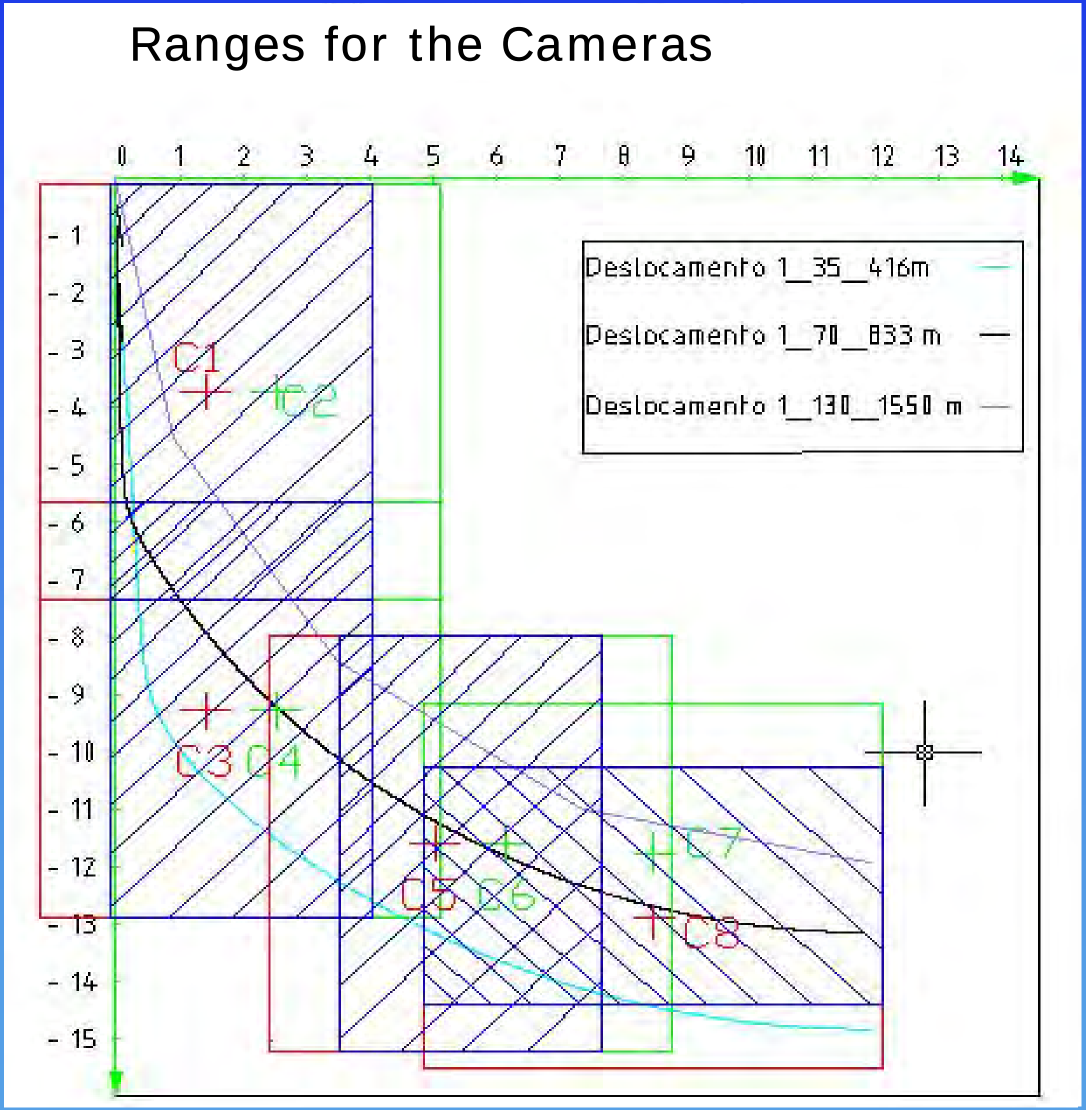


Pendulous Lauching

Plant view

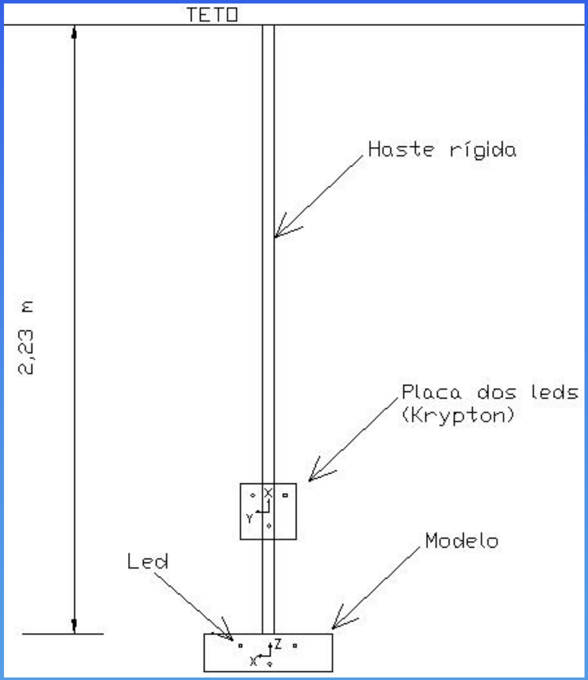


Pendulous Lauching



Instrumentation

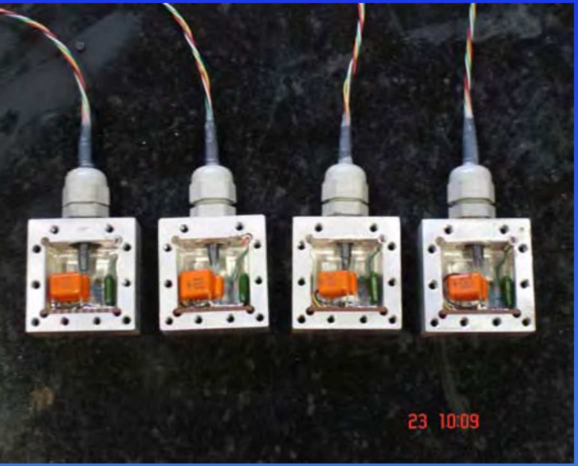
- Initial testing; calibration
- Use of underwater leds



Instrumentation

- 4 Accelerometres bi-axiais
- 3 Rate Gyro
- Load cell
- Data Logger
- 8 Cameras
- Batheries
- 18 LEDS

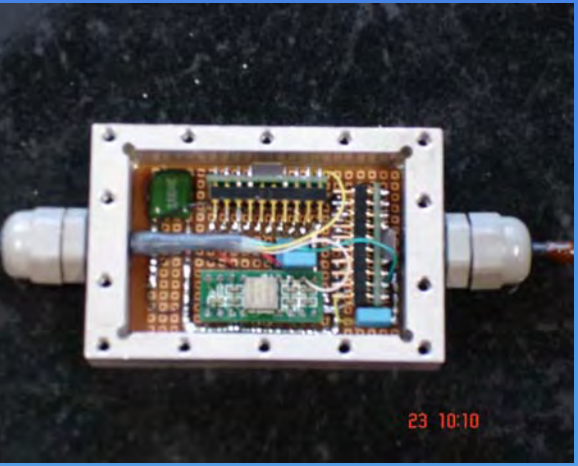
Instrumentation



Accelerometers

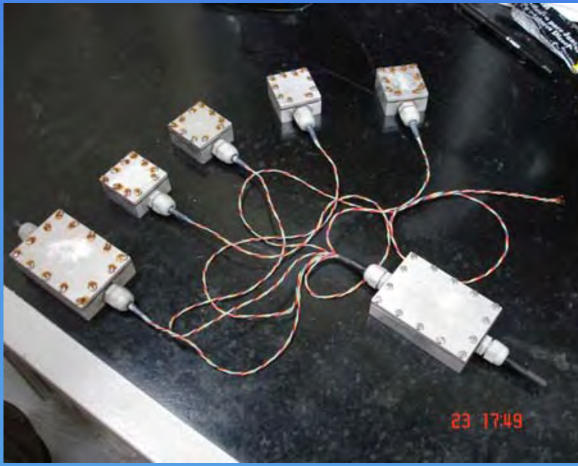
LEDS

Batheries



Rate gyros

Load cell

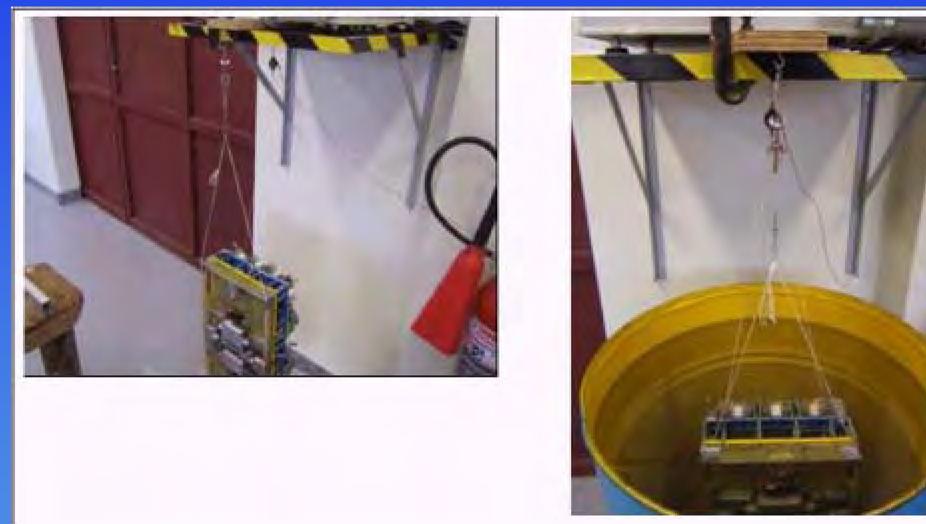


Complete system

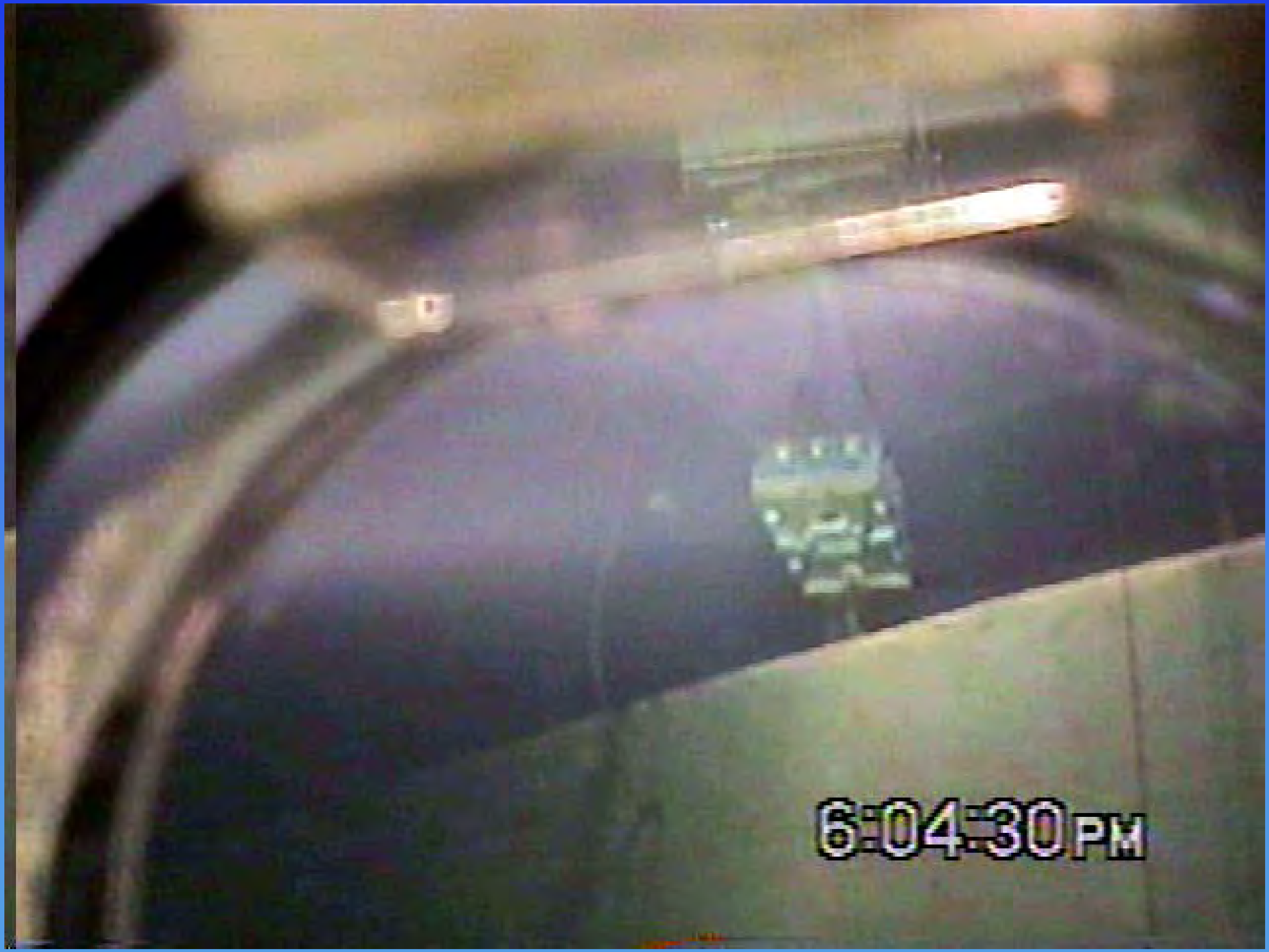
Lines:

Flutuadores	Empuxo (tf)
Lineares	15,68
Distorcidos	10,6

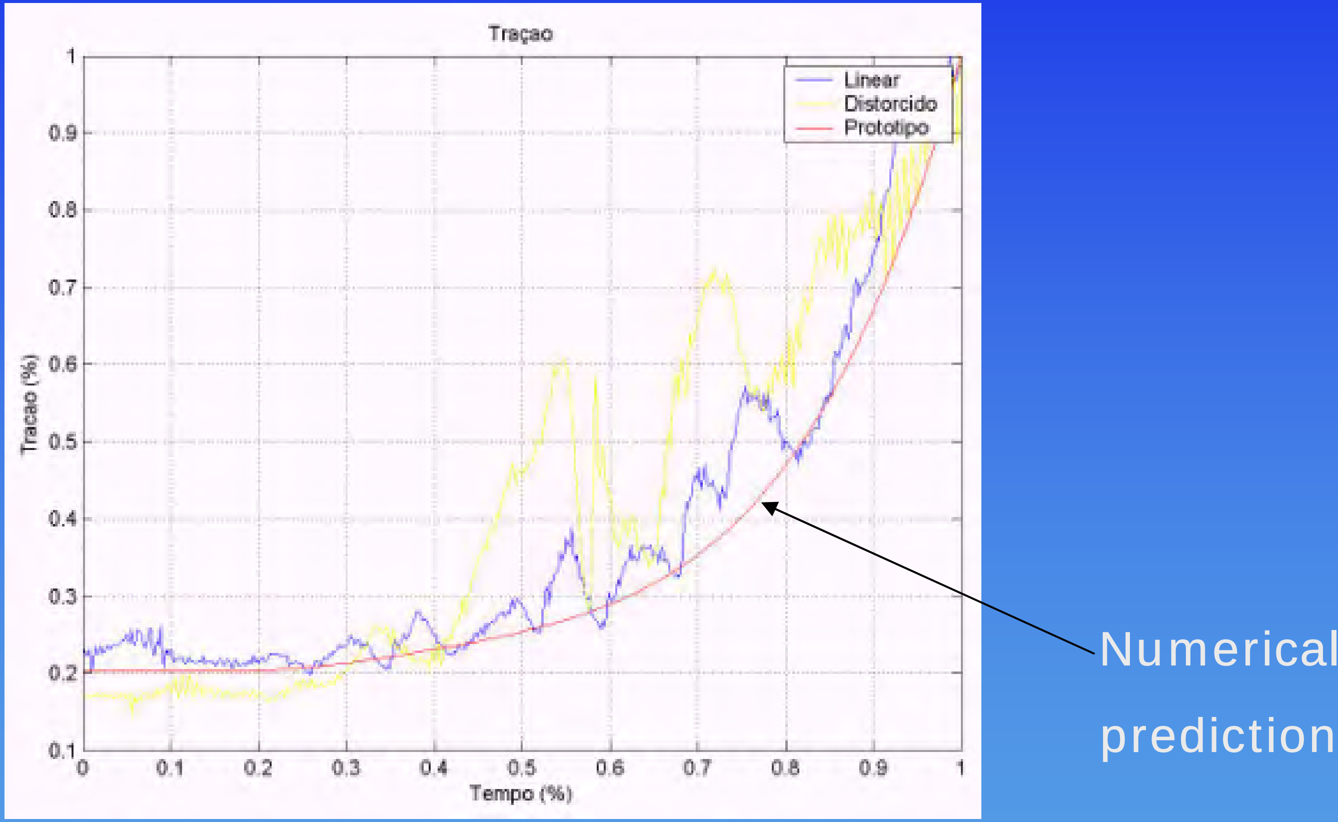
Model calibration



Qualitative underwater videos:

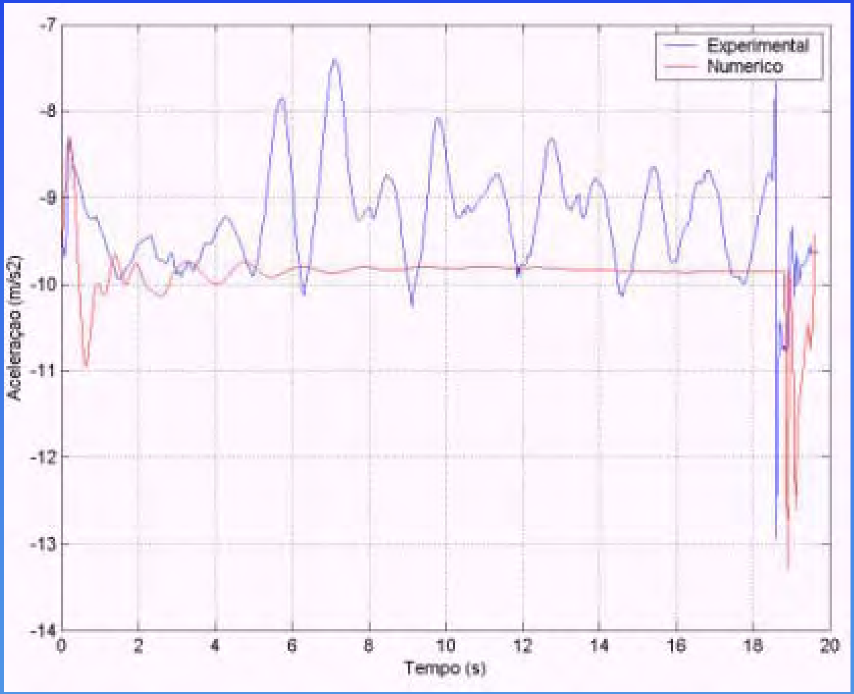


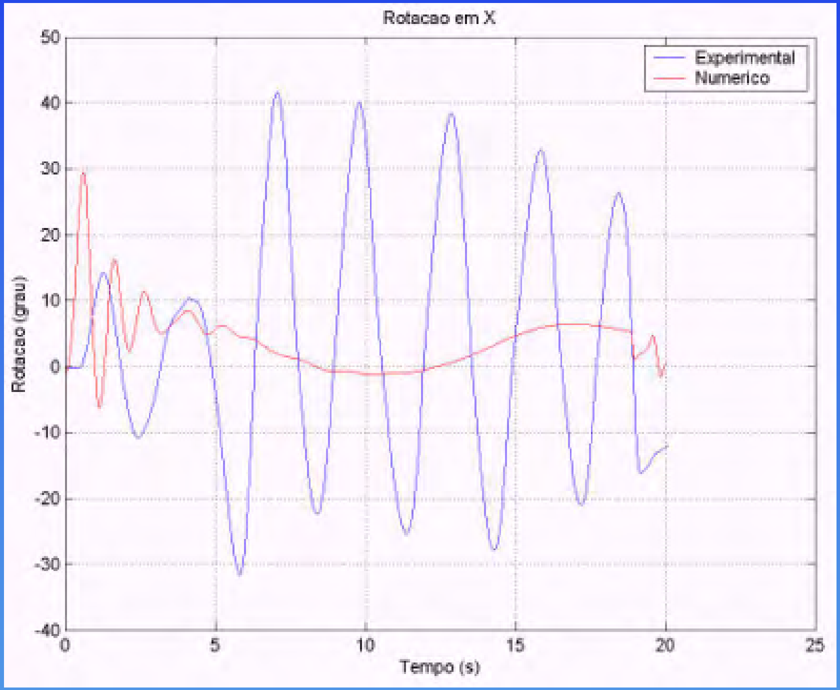
Results:



Tração at the top

Results

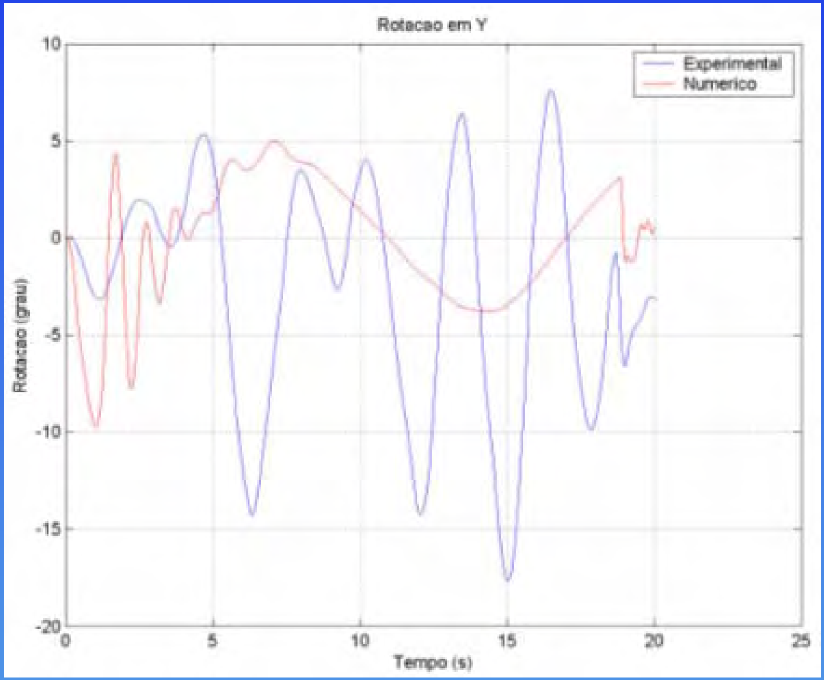


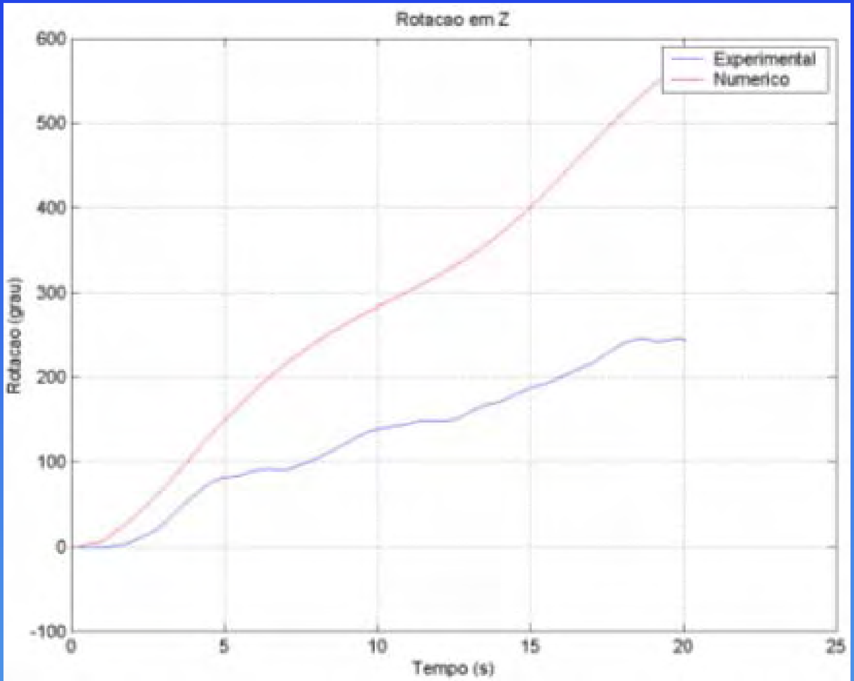


Acceleration (incl. g)

Rotation (X)

Results



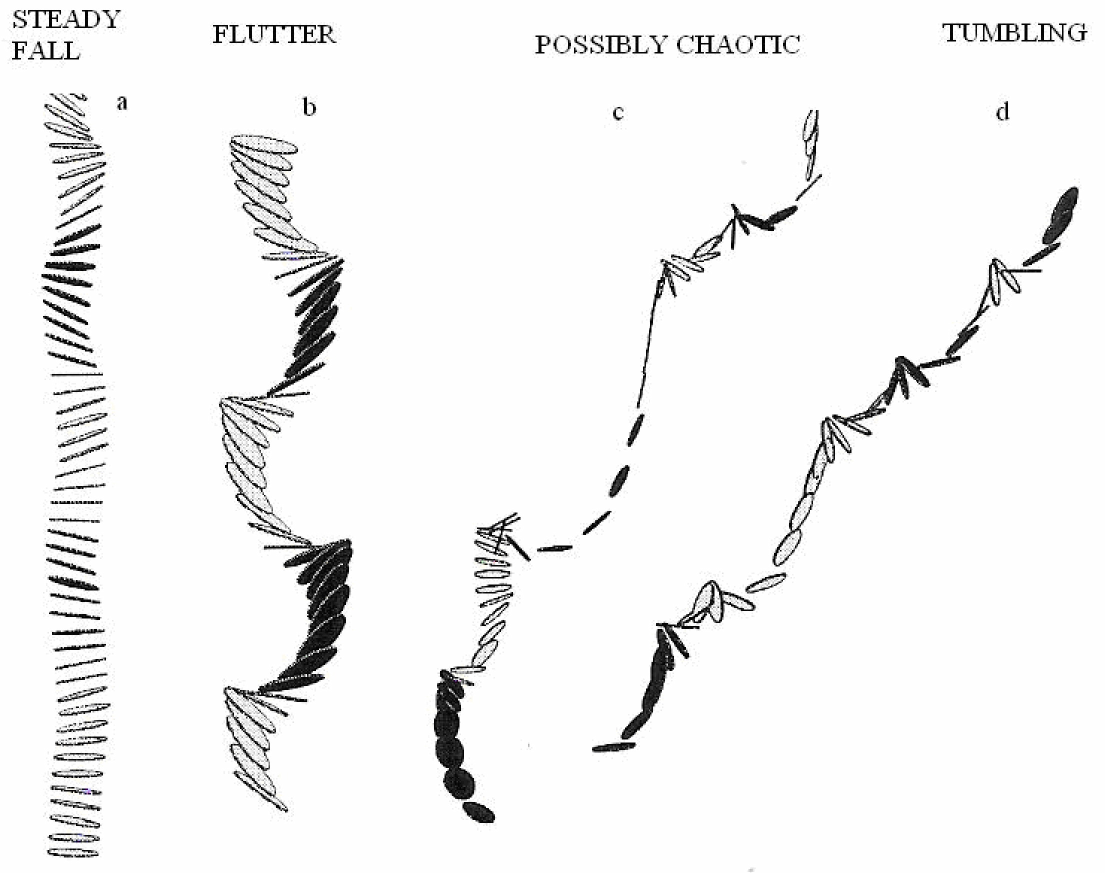


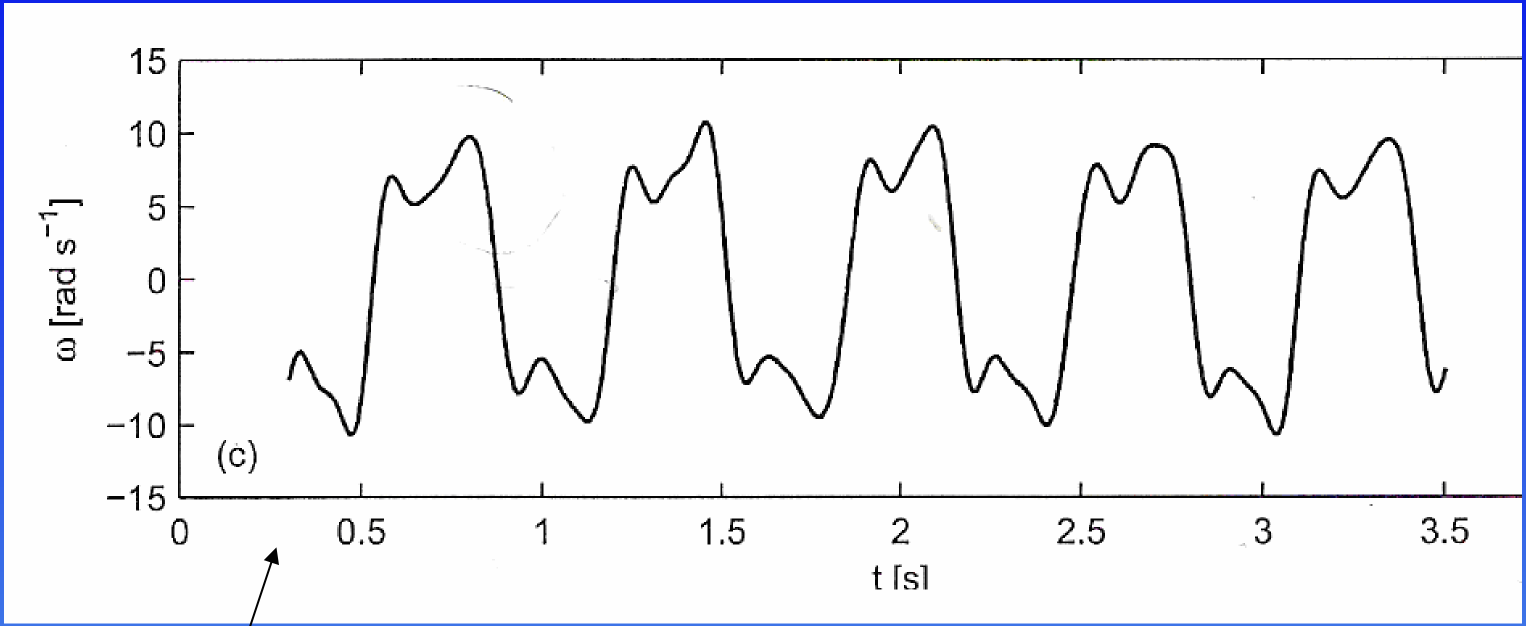
Rotation (Y)

Rotation (Z)

UNEXPECTED BEHAVIOR !

BEHAVIOR IS SIMILAR TO THE FALL OF SIMPLE FORM OBJECTS (Playing cards, leaves, etc)



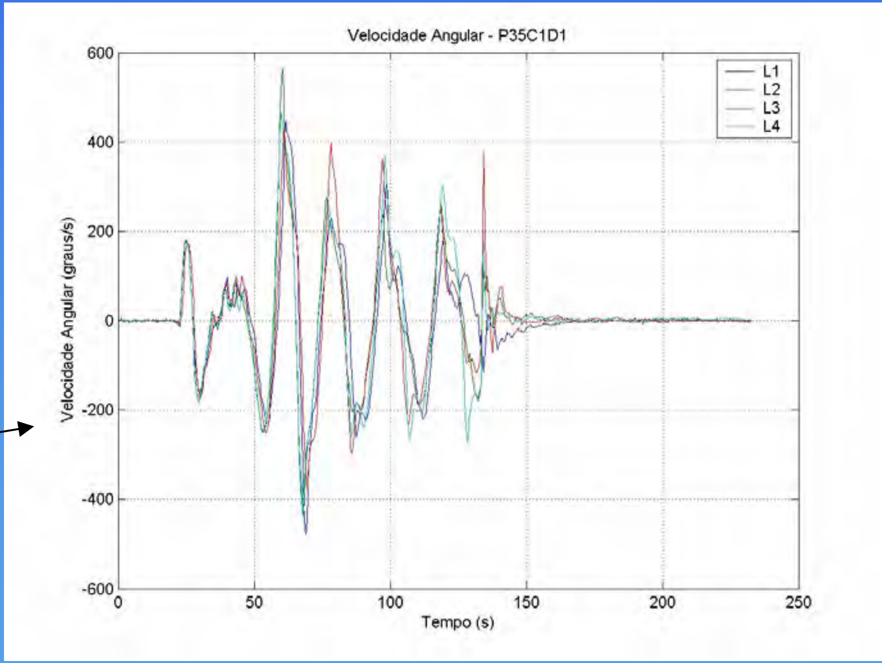


Typical angular velocity behavior

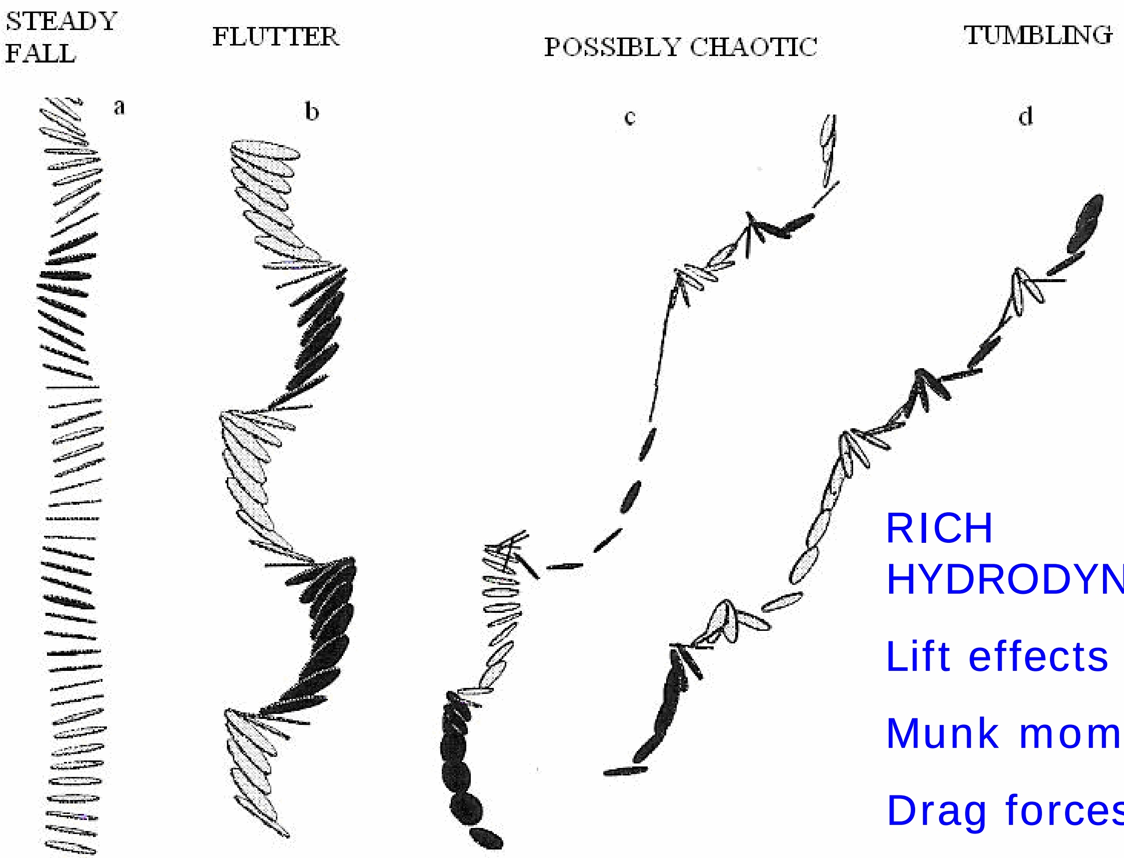
(fluttering)

also

measured during the tests



Comment



RICH HYDRODYNAMICS:

Lift effects

Munk moment

Drag forces

VIV

NA EXPEDITE COMPUTER CODE MUST BE IMPROVED VERY MUCH TO INCLUDE ALL EFFECTS: IT IS NOT IMPOSSIBLE

Conclusions

- The model testing
  - allowed advances in the physical understanding
  - could anticipate problems (rotation)
  - could help to solve the problems by allowing hundreds of solution simulations
  - allowing to devise the most important properties
    - (distortion not really necessary in case
    - porosity really not important
    - inertial rotation is key to control fluttering
    - the terminal velocity is also key for that matter.

THANK YOU!

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