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ALLEGATO 2

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Title:	HYDRODYNAMIC CALCULATIONS – METHODOLOGY AND OUTPUTS	

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1 INTRODUCTION

In order to avoid big cruise ships passing the "Canal Grande", the concept of a floating dock outside Venice is proposed by Vincenzo Di Tella and al. The floating dock will be composed of several pontoon-shaped floaters moored to the seabed and linked to each other.

To check the feasibility of the concept, a model of the whole system will be created with DeepLines^{TM} (see section 6) Hydrodynamic characteristics of the pontoons will be computed by PRINCIPIA with is software Diodore^{TM} (see section 7).

PRI, as technical support, is in charge of the hydrodynamic calculations for this project.

2 PONTOONS DATA

The floating dock is made of 4 identical pontoons each linked to the seabed, and linked between them by a hinge allowing only relative pitch.

The gap between the modules is 1 meter.

2.1 MAIN PARTICULARS

The main particulars of each module are given in the following picture:

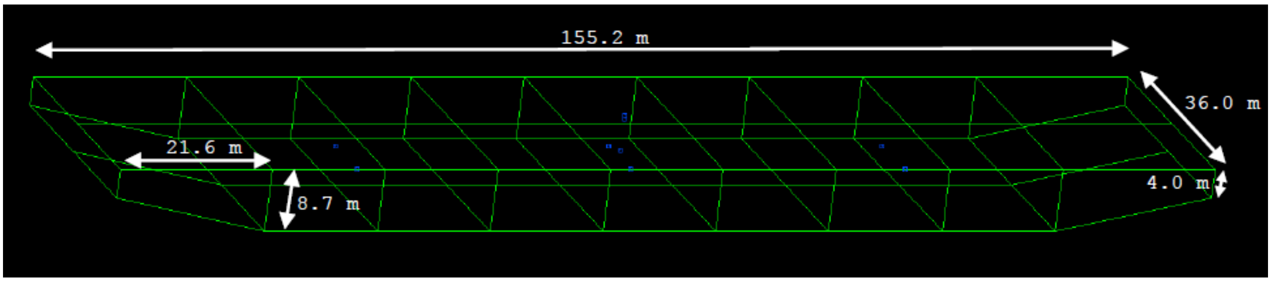


Figure 1: Pontoon main particulars

The loading condition considered is the following:

Parameter	Unit	Value
Draft	m	6.00
Trim	m	0.00
Heel	°	0.00
Mass	t	30615.20
LCG	m	77.60
TCG	m	0.00
VCG	m	6.33
Rxx	m	12.38
Ryy	m	43.36
Rzz	m	43.87

Table 1: Pontoon loading condition

2.2 MOORING MATRIX STIFFNESS

2.2.1 Mooring to the seabed

As per client's requirements, the mooring of each module can be modelled using the following restoring matrix, applied at the centre of gravity:

0.39E+07	0.00E+00	0.22E-03	0.29E+06	0.21E+08	-0.89E+06
-0.39E-05	0.12E+08	0.79E-05	0.67E+08	0.12E+07	0.89E+07
0.85E-04	-0.14E-04	0.12E+07	0.11E+06	-0.40E+06	-0.32E+07
0.65E+06	0.15E+09	0.15E+06	0.84E+09	0.19E+08	0.11E+09
0.46E+08	0.19E+07	-0.45E+06	0.16E+08	0.20E+10	-0.22E+07
-0.20E+07	0.59E+07	-0.16E+07	0.33E+08	-0.93E+07	0.20E+11

Table 2: Pontoon matrix stiffness

Units are m, N and rad.

2.2.2 Link between modules

To model the hinge, modules are linked by a spring with a 1E9 N/m stiffness.

2.3 MESH

A view of half the mesh is given hereafter:

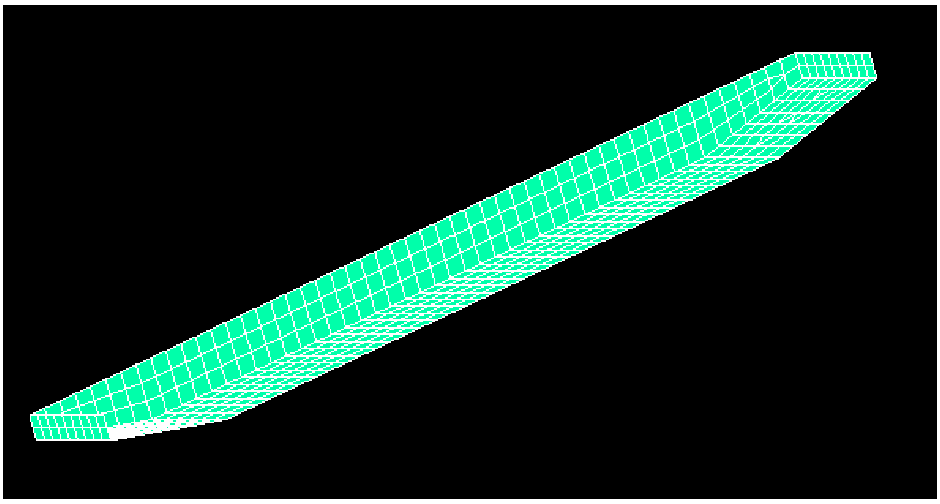


Figure 2: Pontoon mesh view

Aft and fore parts are made with quadrangles whose maximal size is 2 meters. Others parts of the mesh are made with elements having a maximal size of 3 meters.

For the module's hydrodynamic model, the four modules together are considered in order to account the interactions and the coupling between the modules.

3 CRUISE SHIP DATA

3.1 MAIN PARTICULARS

The main particulars of the cruise ship are given hereafter:

Particular	Unit	Value
Length Over All	m	290.00
Beam	m	36.00

Table 3: Cruise ship main particulars

This approximately corresponds to a 110,000 – 120,000 GT.

The loading condition considered is the following:

Parameter	Unit	Value
Draft	m	8.50
Trim	m	0.00
Heel	°	0.00
Mass	t	53448.00
LCG **(*)**	m	126.99
Rxx **(**)**	m	12.00
Ryy **(**)**	m	70.00
Rzz **(**)**	m	70.00

Table 4: Cruise ship loading condition

(*): Centre of gravity longitudinal and transverse positions are adjusted to get neither trim nor heel.

(**): Inertia radiuses are obtained as per the following formula:

$$Rxx = B/3;\ Ryy = Rzz = LOA/4$$

3.2 MOORING MATRIX STIFFNESS

The cruise ships are moored to the modules through synthetic lines and fenders. As per client's requirements, the mooring system can be modelled by the following stiffness matrix, applied at the centre of gravity:

1.6144E+06	-9.8104E+02	-3.9544E-02	6.7502E+00	2.0159E+01	3.0883E+01
-9.6304E+02	3.6550E+06	2.1280E+01	3.3265E+03	9.1378E+02	-2.5723E+02
1.1124E+05	9.9673E+05	7.6352E+05	-1.9102E+07	3.7393E+07	1.5761E+07
-2.6820E+06	7.7709E+06	-1.7384E+07	4.3959E+08	-8.2766E+08	-4.0134E+08
9.8503E+05	-2.5812E+07	3.6399E+07	-8.6306E+08	9.3912E+09	-1.7442E+10
-9.1343E+02	6.2932E+02	-1.6487E+03	-8.3883E+05	5.2440E+08	2.9134E+10

Table 5: Cruise ship mooring matrix stiffness

Units are m, N and rad.

3.3 MESH

A view of the mesh is given hereafter:

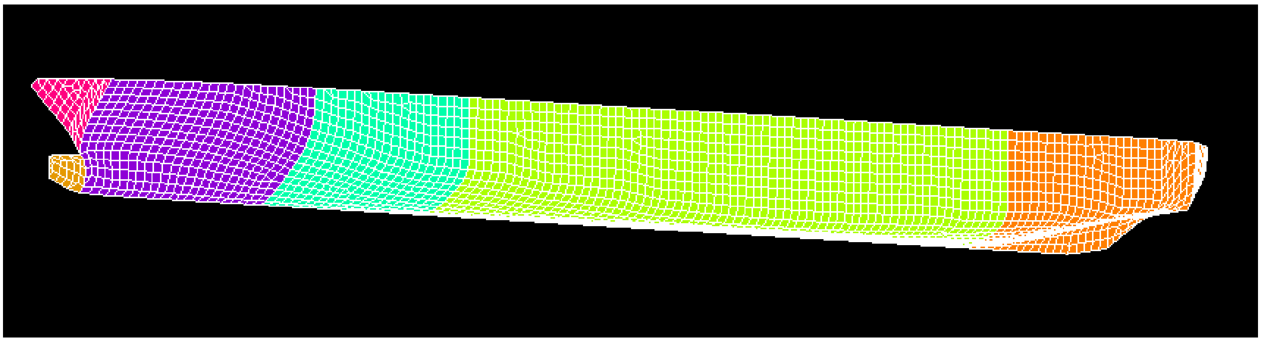


Figure 3: Cruise ship mesh view

For hydrodynamic computations, the vessel alone, without any interaction with modules nor other cruise ship, is considered.

4 SITE DATA

Main data to be considered for the study is the water depth, 11m. It corresponds to a shallow water.

A flat seabed is considered.

5 NUMERICAL ASPECTS AND METHODOLOGY

5.1 DIFFRACTION/RADIATION COMPUTATION

The hydrodynamic analysis includes Diffraction Radiation calculation performed with DIODORE^{TM}. The diffraction-radiation module (potential flow theory) of the sea-keeping tool DIODORE^{TM} is used for a range of wave frequencies (from 4 seconds to 100 seconds) and directions (0° to 360° with at least a 15° step). The following data are included in a Hydro Data Base (HDB):

- Hydrostatic stiffness matrix;
- Added mass;
- Radiation damping;
- First order loads.

As the second order loads also depend on the 1st order motions, a complete DIODORE^{TM} mechanical model (including mass, COG, inertia, mooring system stiffness matrix and all additional damping) is run to get RAO of motions and drift loads.

5.2 DRIFT FORCES

Due to the shallow water, full QTF are considered.

In irregular seas, the Full QTF matrix (quadratic transfer function of the difference frequency wave induced second order loads) needs to be known to express the slowly varying drift force. In many cases so-called Newman’s approximation, based on the knowledge of the diagonal of the matrix only (the drift force in regular waves) provide an acceptable approximation. When the stiffness of the mooring system increases and/or the water depth decreases however, Newman’s approximation underestimates the excitation forces, by far. Exact evaluation of the full QTF matrix is needed.

It is the case of the configurations computed in this study. The water depth is very small compared to the dimension of the modules and the cruise ship. The formulation of the drift force developed in the DIODORE^{TM} software is based on the formulation of the Lagally theorem. As compared to the two classical formulations (near field and far field), this method offers better convergence properties and is valid when several bodies are involved.

5.3 ADDITIONAL DAMPING

5.3.1 Linear low frequency damping

Additional linear damping for low frequency motions is considered for surge, sway and yaw motions.

The values are computed as suggested by the Bureau Veritas in its rule note for permanent moorings (NR 493):

Item	Cruise ship	Module (for each one)
LF damping for surge motion	5.89E+5	7.10E+5
LF damping for sway motion	1.49E+6	1.70E+5
LF damping for yaw motion	1.25E+10	4.21E+9

Table 6: Low frequency linear damping

5.3.2 Roll damping

As potential theory does not account for viscous effects, additional roll damping is added to model the damping due to the friction on the hull and vortex shedding around hull appendages.

The following quadratic damping values are used, as per client's requirements:

Motion	Cruise ship	Module (for each one)
Quadratic damping for roll motion	1.81E+10	1.34E+10

Table 7: Additional roll damping

An harmonic linearization of the damping is used.

5.4 OUTPUTS

Outputs provided are two HDB containing first and second order loads which will be used in DeepLines™ model.

6 APPENDIX A – DEEPLINES™ DATASHEET

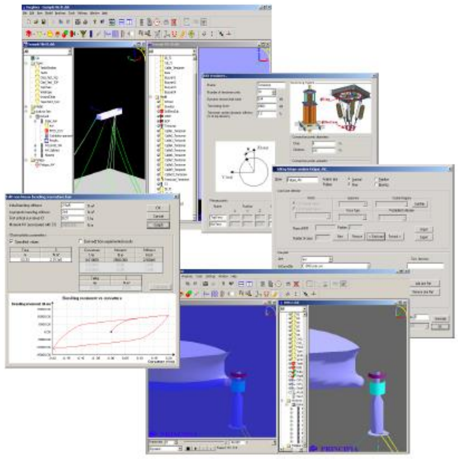
PRINCIPIA

Software Datasheet

DeepLines™

Risers, pipelines and moorings design software

DeepLines™ is part of the marine software solutions developed by Principia and IFP Energies nouvelles. DeepLines™ is based on the finite elements method and forms an integrated software solution to perform in-place and installation analyses of a wide range of offshore structures including flexible and steel risers, umbilical risers, pipelines, floating hoses and mooring lines. The software package combines a powerful finite elements engine featuring advanced modeling capabilities with an intuitive user interface offering optimum productivity through multi-threading.



Applications

- Flexible risers, umbilical and loading hoses
- Production and drilling rigid risers
- Hybrid riser systems such as riser towers
- Mooring lines and multi-body offshore systems
- Subsea equipment installation
- Towed systems analysis
- Pipeline S-lay, J-lay and on-bottom stability analysis
- Design of pipelines and spools submitted to thermal loads

Type of analyses

- Static and quasi-static analysis
- Time-domain dynamic analysis
- Frequency domain dynamic analysis
- Design of drilling riser based on API RP 16Q
- Modal analysis of complete risers and mooring systems
- VIV prediction models
- Fully coupled analysis of floating bodies & lines

Main features

- Time-domain and frequency domain dynamic analyses can both be run from the same GUI
- Powerful and robust finite elements method including coupled bending/torsion effects
- Wide range of boundary conditions
- Non-isotropic 3D seabed friction and suction effect
- Wake models to assess drag loads on lines
- Modeling of sliding device including friction : J-tube, guides, keel-joint, PIP…
- External contact between lines for clashing analysis
- Contact with any user-defined surface, either fixed or moving (soil, moonpool, bellmouth,…)
- Automated detection of contact zones based on proximity criteria
- Non-linear bending stiffness including hysteresis effect for modeling unbounded flexible pipes
- Includes the effect of thermal loads for any type of temperature profile
- Multi-linear stiffness for risers and specific elements to model synthetic ropes
- DNV-OS-F201 and DNV-OS-F101 unity checks are available straight from the user interface
- Assessment of in-line VIV response of pipeline span according to DNV-RP-F105

User interface

- Intuitive user interface including a model browser and 3D view window allowing very efficient model set-up and straight access to analyses results
- Project-oriented model files including all input data and parameters required to run several analyses from the same model file
- Batch processing form enabling automation of large sets of simulations
- Multi-threaded execution of analysis and post-processing tasks
- Easy access to all model data, copy/paste facilities
- Post-processing of a wide range of results for risers, moorings and floating supports : tension, stress, curvature, built-in angles, tensioner strokes, deformed shapes, iso-angle curves for TTRs
- Batch post-processing facilities
- Clearance post-processing form
- Automated export of results to Excel™ and export of AVI files from the 3D View window
- Statistics on every graphs
- Fatigue analysis of steel risers and mooring lines
- Export of .MDS modal database files for input to SHEAR7

Coupled analysis

Fully coupled multi-bodies analyses of offshore systems including support vessels, risers, anchor lines and any other connection such as yokes, etc.

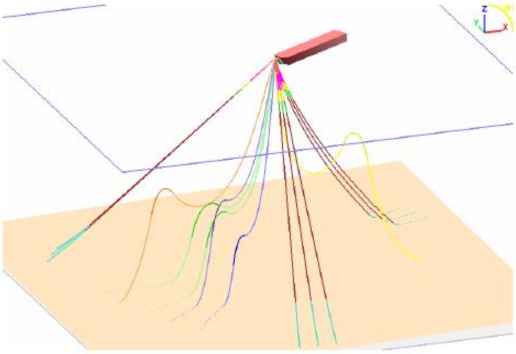
Wind, current and wave loads on the floating body

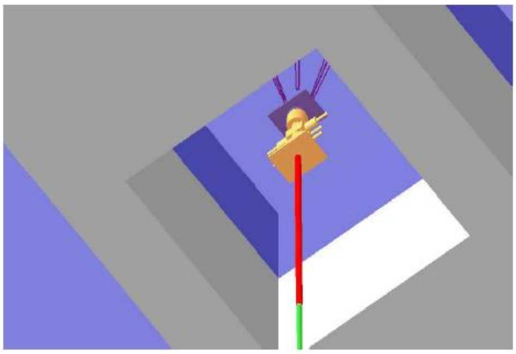
- Wind, current and wave loads on the floating body
- Low-frequency motion (based on Newman's approximation or full QTFs)
- Wave frequency coupled analysis in time-domain or frequency domain with regular or irregular waves

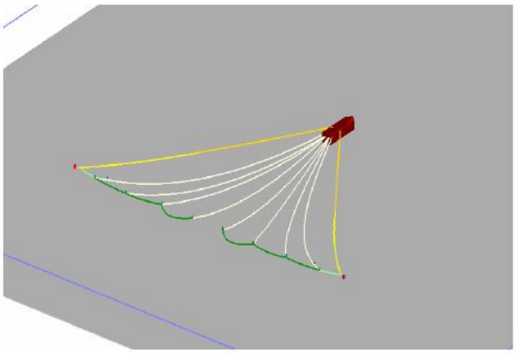
Definition of hydrodynamic properties of support vessels through simple text files

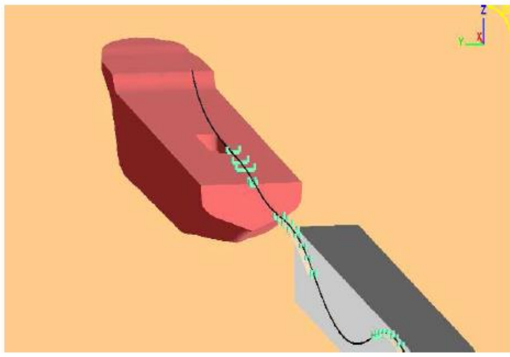
Technical support

Best in class client support is provided by email at deeplines@principia.fr. Our team of experienced risers design engineers will always be pleased to bring timely responses to all your queries.









www.principia.fr
deeplines@principia.fr

Head Office
215 Voie Ariane,
ZI Athelia 1
13705 La Ciotat
France
Tel: +33 442 98 11 80
Fax: +33 442 98 11 89

Nantes
Rue de la Noë
44000 Nantes
France
Tel: +33 240 14 50 14
Fax: +33 240 14 34 00

Houston
C/O Forum Services
1900 West Loop South,
Suite 850 Houston, TX
77027 USA
Tel: +1 713 993 0797
Mob: +1 713 291 8429

Singapore
PAPE Engineering
12, Cyberhub @IBP #02-03
609920 Singapore
Tel: +65 65 050 300
Fax: +65 65 050 301

Denmark
PRINCIPIA North A/S
Kullinggade 29
5700 Svendborg - Denmark
Tel: +45 62 228 228
Mob: +65 22 169 811

Diodore™

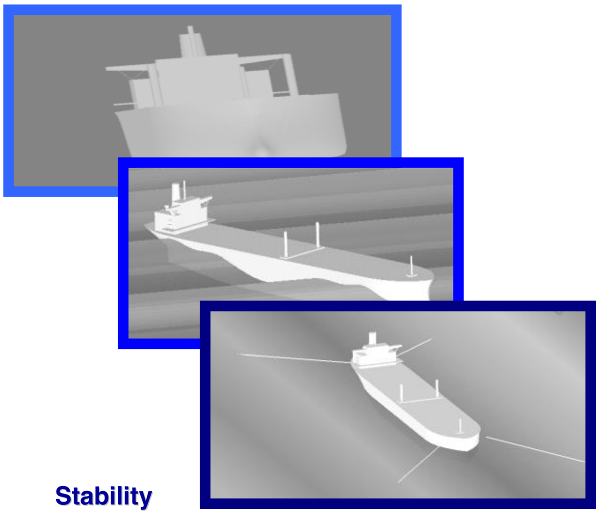
PRINCIPIA

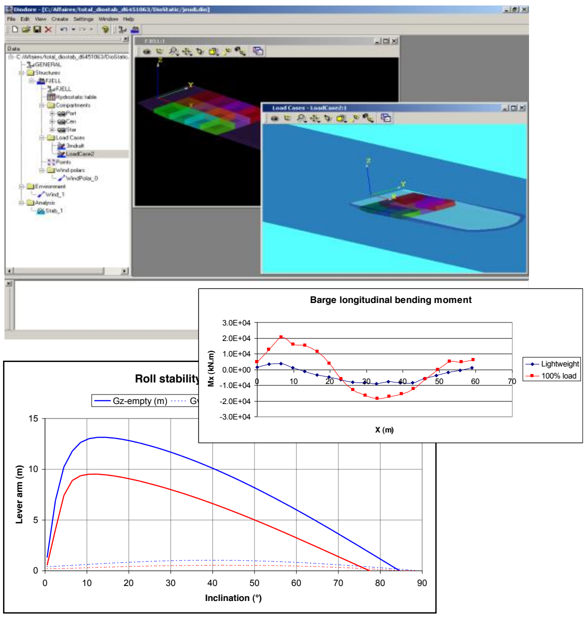
An hydrodynamic integrated software solution

Diodore™ V4 is a versatile hydrodynamic integrated software. Main applications are:

- ❑Stability
- ❑Seakeeping
- ❑Mooring and berthing

It is developed and validated by Principia since 1981 in cooperation with IFP (Institut Français du Pétrole) and Bureau Veritas.
Basically it is a panel based software organised to bring to the engineers a practical tool to assess any design matter linked to hydrostatic/hydrodynamic from conceptual studies to detailed analysis.





Stability

This module addresses flotation, trim, stability, and strength calculation.
It is general purpose as the calculation of the involved loads (on the hull and tanks) is based on a panel integration.
Therefore any structure, mono-hull, multi-hull, semi-submersible, SPAR can be analysed.
It can be handled both the Graphic User Interface or the ASCII input file.
From Gz curves and Gv curves, any criteria can be defined to permit assessing regulatory requirements from any classification societies.
Validations rely on the development of On-board applications based on this module which have been certified by Bureau Veritas.

Reference

Logiciel de calcul de stabilité embarqué fondés sur le logiciel Diodore™ , N. Couty, et al. ATMA 2007

Seakeeping

This application is based on a 3D diffraction-radiation solver.
It calculates the wave loads and motions of one or several structures, free floating or restrained by mooring systems. The program is applicable to structure with or without forward speed, from deep to shallow water.

Hydrodynamic loads

Compelling features of the hydrodynamic processor are :

- ❑Computation of 1st order quantities: added mass, radiation damping, diffraction and excitation loads
- ❑Multi-body interactions
- ❑Sloshing modal analysis in tanks
- ❑Forward speed free surface conditions (encounter frequency to full methods)
- ❑Total hydrodynamic pressure on each panel

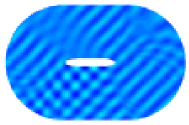
Motion

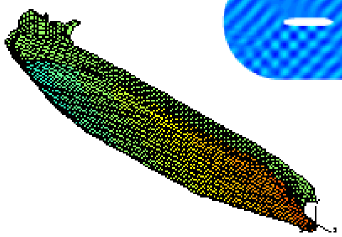
Motion transfer functions are the basic outputs of a sea-keeping analysis and Diodore™ computes platform motions with the following high level options:

- ❑Linear and quadratic damping
- ❑Stochastic or harmonic linearisation of the damping
- ❑Roll damping State of the Art formulation (ITH Ikeda, Tanaka and Himeno, rudder, stabilizers and skeg)
- ❑Rudder and Foil control in frequency domain
- ❑Sloshing-seakeeping coupling
- ❑Moonpool and gap hydrodynamic models through lid technic

Strength

Global loads transfer functions and spectral response are computed for ship hull girder as well as for any element of an offshore platform (substructures)
Full coupling with FEM software such as NSO or Abaqus™ is also available





Validation

Diodore™ was used in the FPS 2000 comparison tests within the NTNF research program (Norway) along with 23 other international organizations in 1996.
Diodore was amongst the software used for the benchmark in HAWAI JIP in 2006-2007 for 1st and 2nd order wave loads (full QTF) in shallow water.

References

Validation mutuelle des différents codes de tenues à la mer, J-F Le Guen, A.R. Magee, C. Royal 4ème Journée de l'hydrodynamique, 1993, Nantes

Validation of a 3D Seakeeping software, T. Coudray, J-F. Le Guen, 1994, CFD Computation, Madrid

ISOPE Roll

FPSO Roll damping prediction from CFD, 2D and 3D model test investigation, A. Ledoux, B. Molin, C. De Jouette, T. Coudray, ISOPE 2004

Coupling between liquefied gas and vessel's motion for partially filled tanks: effect on seakeeping, A. Ledoux, G. Gaillarde, M. Lynch, LNG Carrier Design and operation RINA Conference 2004