Report

2008 Annual WAMIT Consortium Meeting

October 14-15, 2008

Woods Hole, Massachusetts

Agenda for 2008 Annual WAMIT Meeting
Room 310, Marine Resource Center, Swope Center, Woods Hole, MA

October 14, 2008:

9:00AM: Welcome

9:15AM: "WAMIT V6.4"
J. N. Newman, WAMIT

10:00AM: "WAMIT V6.3S"
C.-H. Lee, WAMIT

10:40AM: Break

11:10AM: "MultiSurf developments for WAMIT"
J. S. Letcher, R. Page, M. Shook AeroHydro

12:00PM: Lunch, Swope Center Dining Hall

1:40PM: "Mitigation of Noise from Drilling Operations Using Bubble Curtains"
R. Mercier , OTRC

2:20PM: "Wavemakers and Absorbers""
J. N. Newman, WAMIT Inc.

3:00 PM: Break

3:30 PM: "Technical Discussion"

5:30PM: Mixer and Dinner, Swope Center Dining Hall

October 15, 2008

9:00PM: “Current activities and future plans”
C-H Lee WAMIT , Inc

10:30AM: Break

11:00AM: Business meeting

12:00AM: Lunch, Swope Center Dining Hall

Contents

~~New features to be introduced in V6.4~~

~~(25 September 2007)~~

New features introduced in V6.4

(7 October 2008)

V64 extensions -- Last year's list

- Automatic interior free-surface discretization with higher-order method
- Breaking long runs of POTEN
- Walls and Wavemakers
- Trimmed waterlines

V64 extensions -- additional items

- Option to use two separate csf files for control surface (only if they are defined by user)
- Automatic discretization of exterior control surfaces for momentum drift forces (Option 9c) -- (ILOWHI=0,1)
- IRR(n) can be a vector for NBODY>1
- IGENMDS can be a vector for NBODY>1
- IRR, ISX,ISY, NPATCH passed to GEOMXACT
- GDF filename can be used in NEWMODES.DLL
- indices of dipole panels or patches can be input in the CFG file
- More options in RG2WAMIT (MultiSurf interface)
- V64 built with Intel Visual Fortran (IVF)
- Extended versions of GEOMXACT and NEWMODES and supplementary test runs to be available to download from the web
- Tank free surfaces can be defined with new parameter ZTANKFS

Automatic discretization of interior free surface using the higher-order method

(for irregular-frequency removal)

IRR=3: program automatically derives patches for all interior free surfaces

(IRR=2 is not used with the higher-order method)

Methodology

- Identify patches and sides which form one or more closed waterlines
- For each closed waterline identify an axis (point or line) in the interior from averaging vertex coordinates
- Define new interior-free-surface patches, one for each exterior patch unless this is not needed (e.g. at a transom stern)
- Use ruled mapping on each new patch
- If waterline slope changes substantially (> 0.5 radian), use polar mapping (e.g. at bow of FPSO or on each waterline of a semi-sub)

Special notes

- Internal free surfaces such as moonpools are not supported (interior free surface must be simply connected)
- Spline parameters for the interior free surface are assigned to give continuity with the exterior patches (same panel subdivision along the waterline and similar panel widths normal to the waterline)
- Algorithms may fail for irregular or complicated cases
- Users should plot the _pat.dat and _pan.dat output files to verify that the interior free surface representation is OK
- This option is particularly useful with trimmed waterlines
- Applicable for ILOWH=1 only

Breaking long runs of POTEN

For most first-order WAMIT runs the computational time is spent primarily in POTEN, on the set-up and solution of the linear system of equations for the velocity potential. This occurs in a loop over NPER wave periods, as specified in the .POT input file for the run. It is not unusual to underestimate the time required for the POTEN run. In this circumstance the user may want to break the run and save the solutions which have been computed, for use in FORCE. This has not been possible with V6.3 or prior versions of WAMIT.

Method

A new optional input file can be used, with the reserved filename **`break.wam`** If this file does not exist then the run continues normally without breakpoints. If **`break.wam`** does exist and can be opened, then the program pauses for interactive input by the user at two points within the period loop: (a) before setting up the LHS, and (b) before solving the linear system. Since the **`break.wam`** file is not read, its contents are irrelevant. This file can be set up either before or during the run. (The simplest procedure is to copy any other existing file to **`` `break.wam ``**'.)

Options for interactive input

If the file **break.wam** exists and can be opened, then at each breakpoint the user is requested to input one of three choices:

B or **b**: Break run and continue with reduced NPER

C or **c**: Continue run and keep BREAK.WAM

D or **d**: Delete BREAK.WAM and continue run

In case **B** the result is the same as if NPER was reduced with the new value NPER=JPER-1, where JPER is the current index of the wave period in the loop.

Walls and Wavemakers

2 years ago we presented initial work on this topic, restricted to the analysis of the radiated wave field generated by one or two banks of wavemakers situated in the wall(s) X=0 and/or Y=0 of a semi-infinite wave tank. That capability is included in V6.3. It has been used extensively by John O'Dea to analyze proposed new wavemaker systems for the seakeeping basin at Carderock. (See O'Dea & Newman, ATTC 2007, available for download from www.wamit.com)

Computational Approach in V6.3

- Represent geometry by low- or higher-order panels/patches (wet side only)
- Set up RHS of linear system (source strength)
- Set velocity potential = 0 on body surface, and skip solution of linear system (ISOLVE=-1)
- Only radiation modes are considered, no incident waves or diffraction.
- Supported outputs include only options 6&7 (wave elevations, pressures, fluid velocities)
- No other bodies can be present in the fluid domain
- Other walls are open boundaries

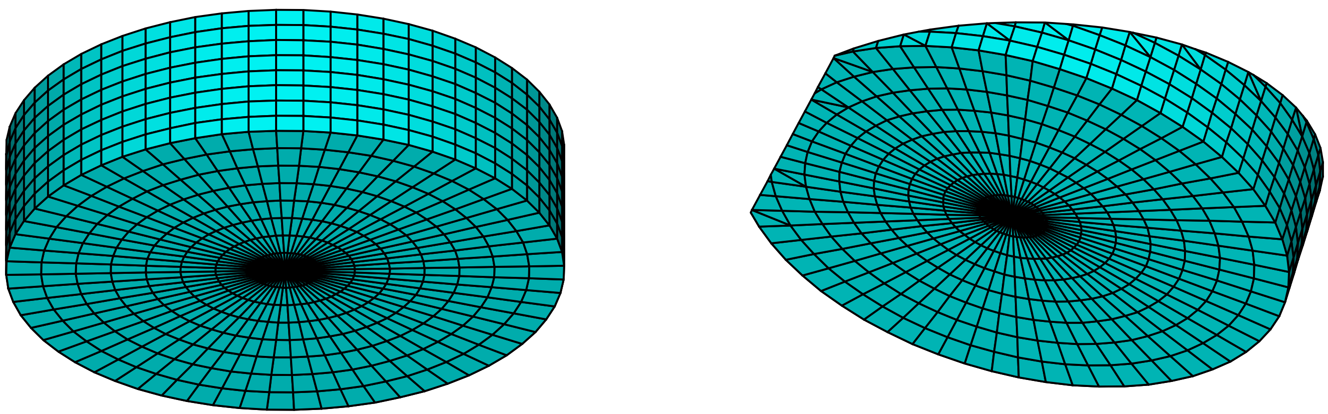
New methodology

- Allow for one or two reflecting walls to be present, coinciding with the plane(s) X=0 and/or Y=0.
- This approach has always existed in the low-order method (ISX,ISY=-1,-2)
- New approach applies for both low-order and higher-order methods
- All options are supported except momentum drift forces (Option 8)
- Bodies can be present in the fluid
- Wavemakers can be present on the walls

Trimmed waterlines

- ITRIMWL=1 in CFG file
- XTRIM(3) = (heave, pitch, roll) (Euler)
- Low-order or higher-order
- Body must be defined in GDF up to Z=0 or higher

Trimming waterline of low-order circular cylinder

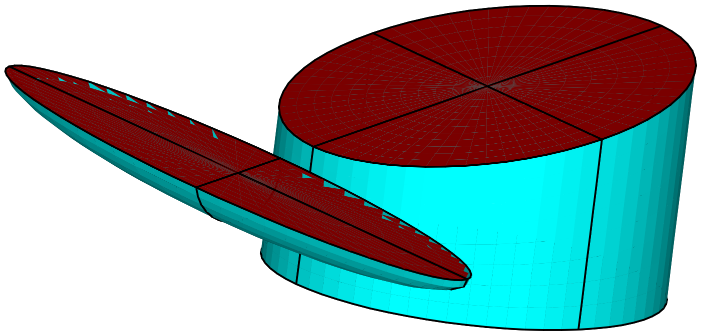


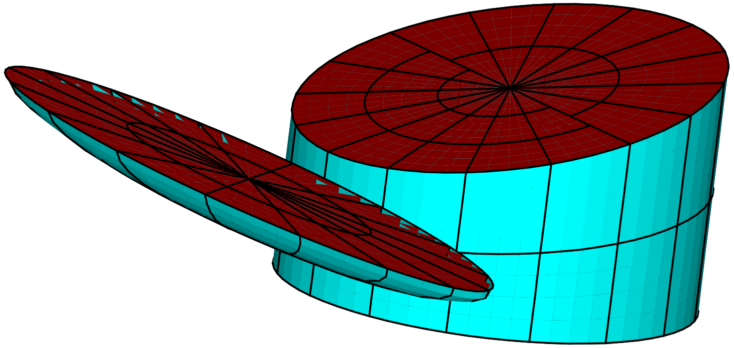
Test 13 (NBODY=2)

Cylinder is trimmed, spheroid is not

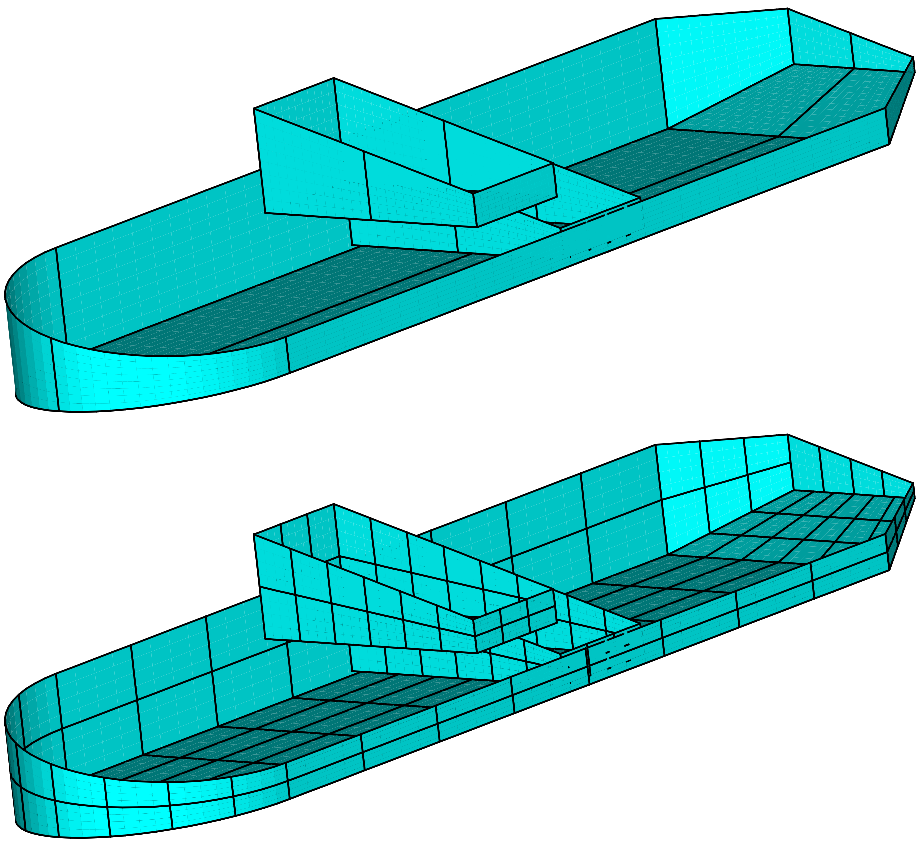
Spheroid GDF includes interior free surface , IRR=1

Cylinder GDF does not include interior free surface, IRR=3



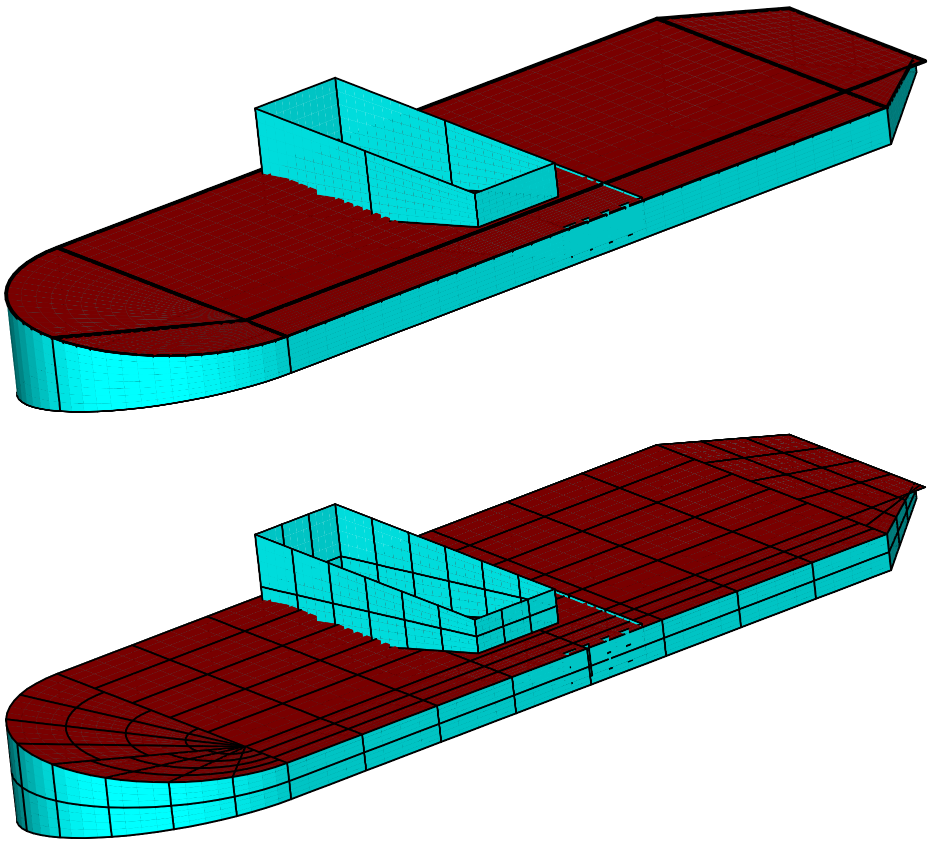


Test 22 FPSO rolled 15 degrees



Test 22 FPSO rolled 15 degrees

IRR=3

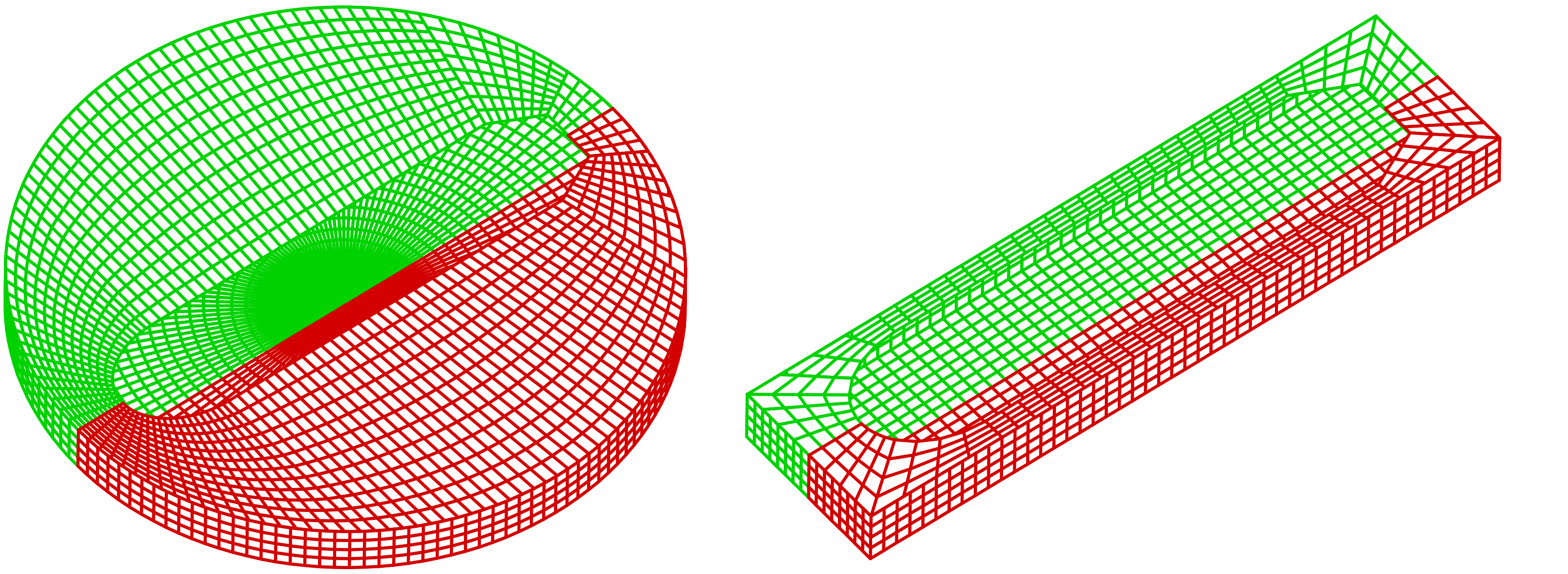


Automatic Control Surfaces (for option 9c)

- Option 9c evaluates drift forces from momentum flux through a control surface surrounding the body
- ICTRSURF=1 input in CFG file (simple)
- Various options to represent geometry, analogous to body geometry options (more work)
- Inputs in CSF file analogous to GDF
- New option: automatic generation of control surface
- Analysis of intermediate free surface is similar to IRR=3 method for interior free surface, but more general (applicable for both ILOWHI=0 and ILOWHI=1)

Circular and rectangular control surfaces

Test22 FPSO



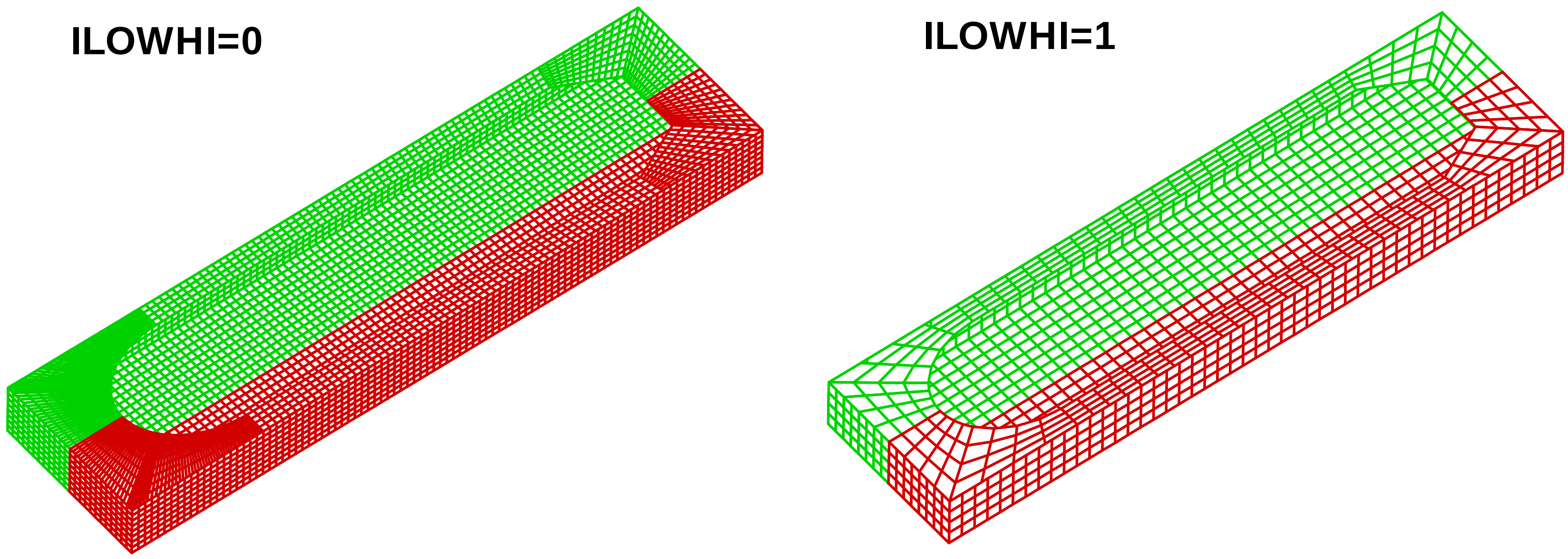
Examples of CSF files for TEST22 FPSO
(L=20m, B=4.4m, T=1.2m)

```
 test22.csf  FPSO, circular outer boundary
1   ILOWHICSF
0  1        ISX  ISY
0   0  2. NPATCH  ICDEF  PSZCSF  (1st two indicate this is automatic)
  12.0  2.0    RADIUS, DRAFT of outer box
  0   NPART      No quadrilateral partitions required
```

```
 test22.csf  FPSO, rectangular outer boundary
1   ILOWHICSF
0  1        ISX  ISY
0   0  2.  NPATCH  ICDEF  PSZCSF  (1st two indicate this is automatic)
  0.0  2.0    RADIUS, DRAFT of outer box
  1   NPART  1 quadrilateral partition on outer boundary
  4   nv0      4 vertices on outer boundary
  12.0   0.0
  12.0   3.0
 -12.0   3.0
 -12.0   0.0
```

Automatic CSF works for both low-order and higher-order

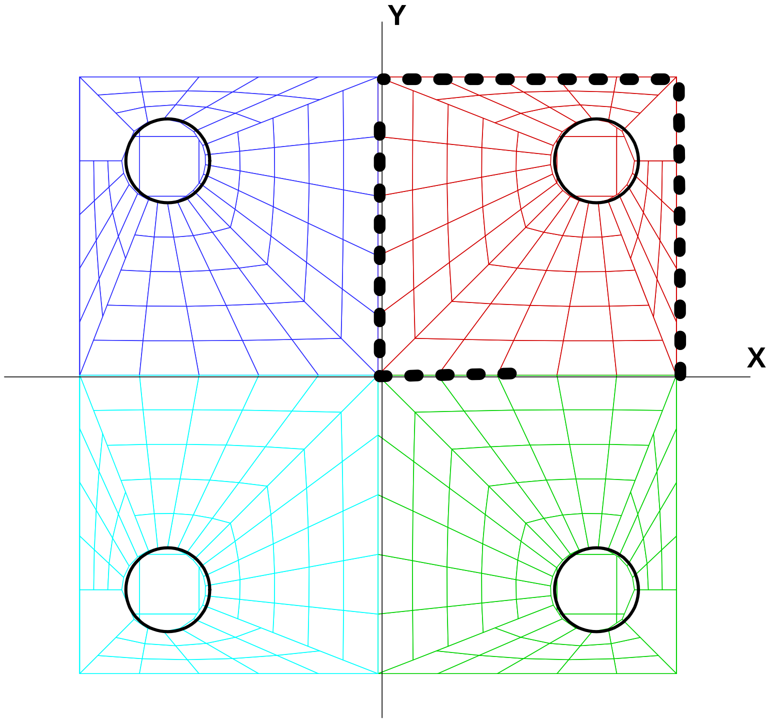
(FPSO used in Test22)



CSF file for ISSC TLP

(square outer boundary)

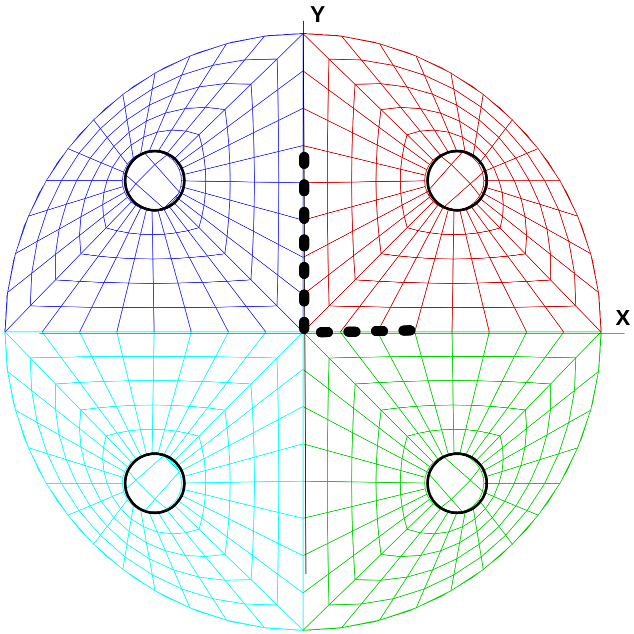
```
 test14.csf  TLP, outer box 60*60*40
 1   ILOWHICSF
 1  1        ISX  ISY
 0   0  10. NPATCH  ICDEF  PSZCSF
0.0  40.0    RADIUS, DRAFT
2   NPART
  3   nv0
  60.0   0.0
  60.0  60.0
    0.0  60.0
3    nv1
4    0.0  50.0
   0.0  0.0
  30.0  0.0
```



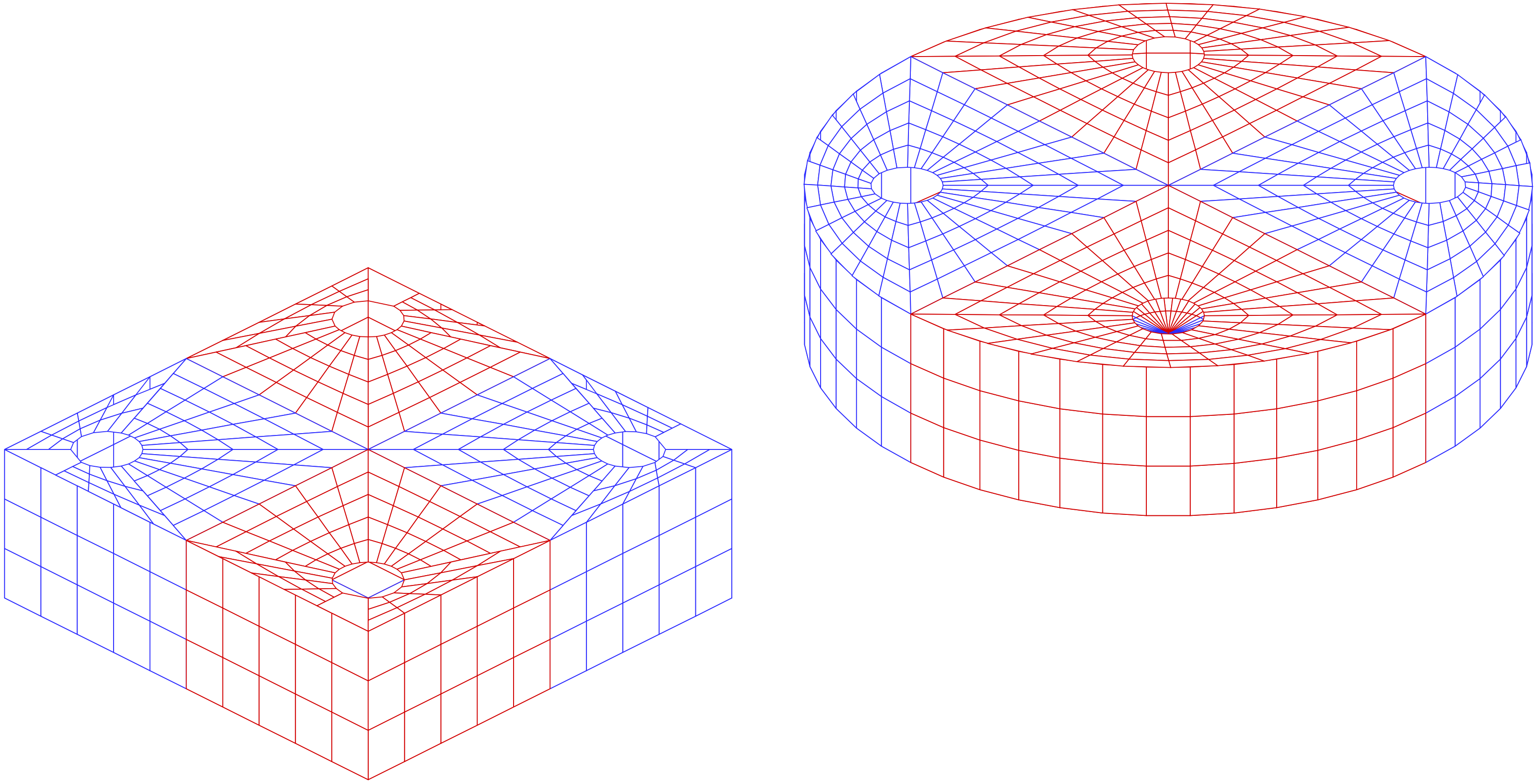
NB: the outer and inner partitions must be defined separately since they are used differently (outer to form outer box, inner only on free surface)

CSF file for ISSC TLP
(circular outer boundary)

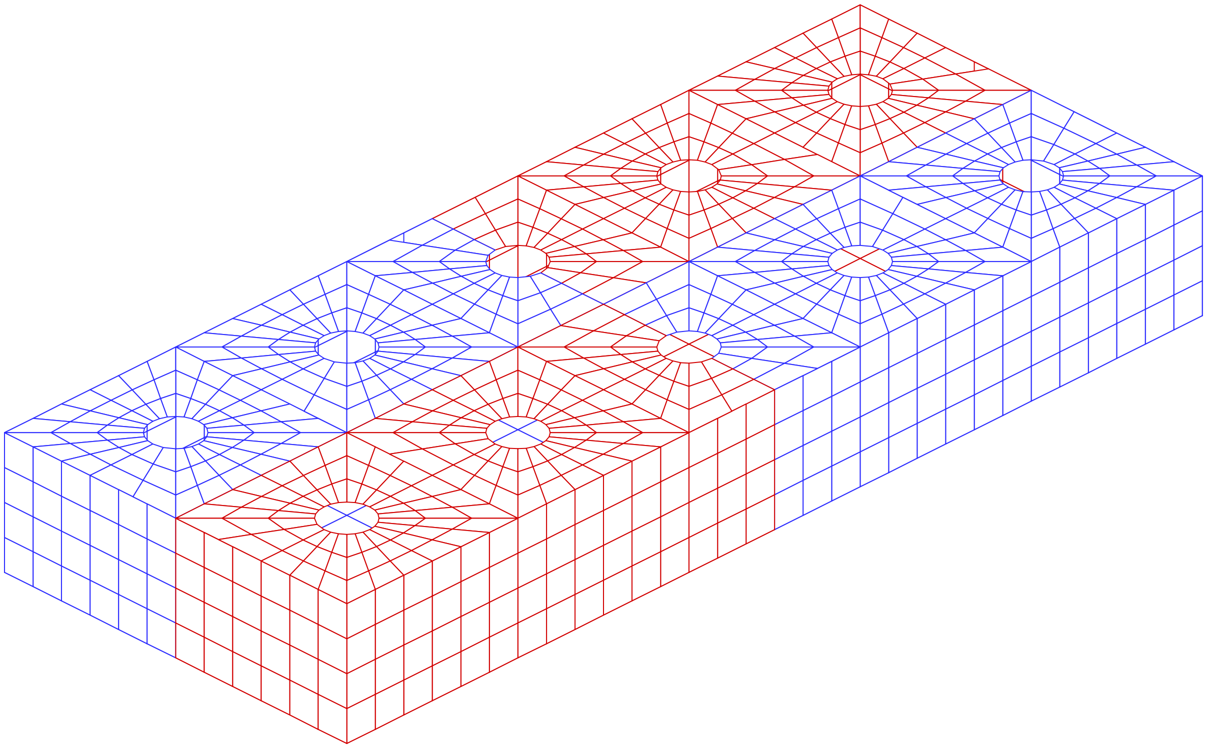
test14.csf TLP, circular cylinder outer boundary
1   ILOWHICSF
1 1   ISX ISY
0   0 10. NPATCH ICDEF PSZCSF   (1st two indicate automatic)
85.0 40.0   RADIUS, DRAFT of outer box
1   NPART
3   nv1
0.0 50.0
0.0 0.0
30.0 0.0



TLP Control Surfaces



Semi-Sub Control Surface



CSF file for Semi Sub (rectangular outer boundary)

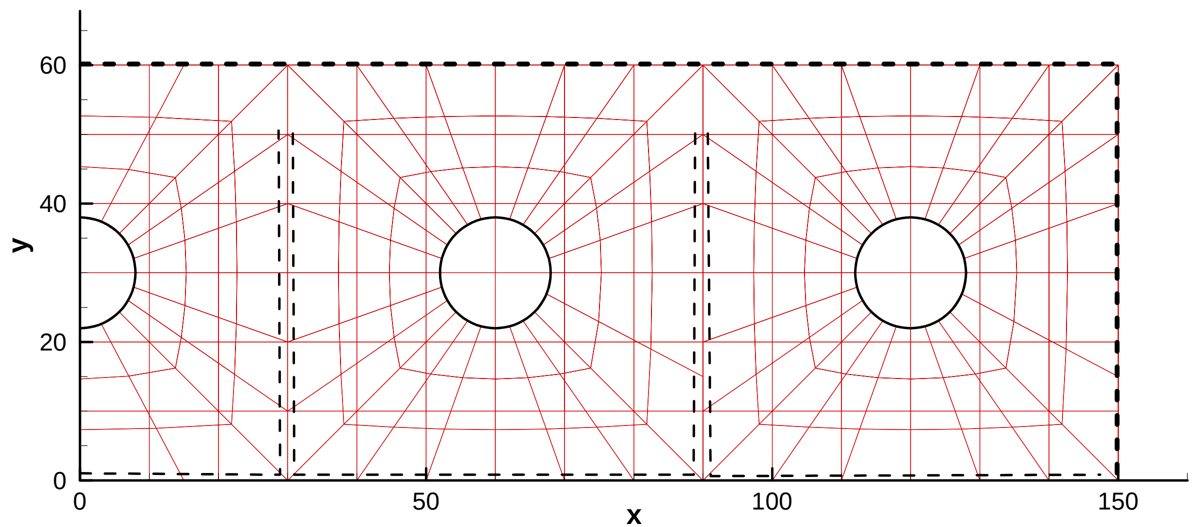
```
  test15.csf  semi sub
1   ILOWHICSF
1  1        ISX  ISY
0 0 10. NPATCH ICDEF PSZCSF
 0.0  40.0    RADIUS, DRAFT
  4   NPART
  3   nv0
  150.0   0.0
  150.0  60.0
    0.0  60.0
  3   nv1
   0.0  0.0
  30.0  0.0
  30.0  50.0
  4   nv2
  30.0  50.0
  30.0  0.0
  90.0  0.0
  90.0  50.0
  3   nv3
  90.0  50.0
  90.0  0.0
  150.0  0.0
```

Gaps are shown for clarity
No gaps or overlap allowed.

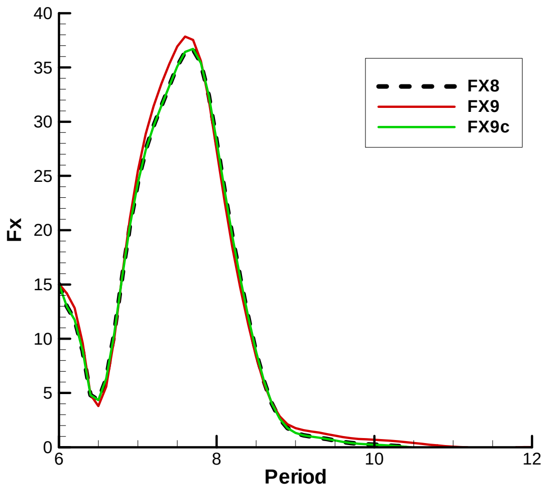
Partitions are extended to intersect the outer boundary automatically

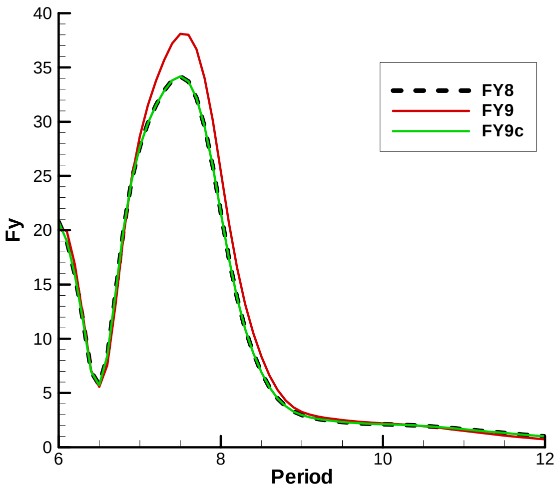
No inner partition on y-axis since ISX=1

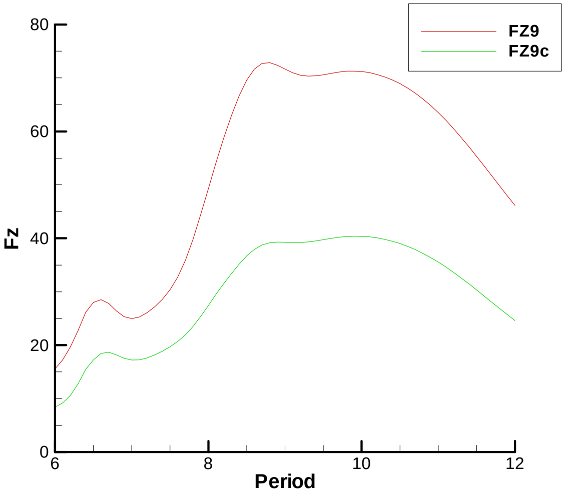
The order of the partitions in the CSF file must correspond to the order of the waterlines in the GDF!



Comparison of drift forces on Semi-Sub in oblique waves







V64 extensions -- Summary

- Automatic interior free-surface discretization
- Breaking long runs of POTEN
- Walls and Wavemakers
- Trimmed waterlines
- Option to use two separate csf files for control surface
- Automatic discretization of exterior control surfaces
- IRR(n) can be a vector for NBODY>1
- IGENMDS can be a vector for NBODY>1
- IRR, ISX,ISY, NPATCH passed to GEOMXACT
- GDF filename can be used in NEWMODES.DLL
- indices of dipole panels or patches can be input in the CFG file
- More options in RG2WAMIT (MultiSurf interface)
- V64 built with Intel Visual Fortran (IVF)
- Extended versions of GEOMXACT and NEWMODES and supplementary test runs to be available to download from the web

V64 built with Intel Visual Fortran (IVF)
(V6.3 and earlier built with Compaq CVF)

- 10-20% faster than old versions
- CVF no longer available or maintained
- DLL files built with either CVF or IVF can be used with new version of WAMIT.EXE
- IVF requires extra DLL files: *libifcoremd.dll* and *libmmd.dll* (redistributed with WAMIT.EXE)
- Some older systems also require Microsoft Visual C++ 2005 Redistributable Package (See User Manual Section 2.1)

Good News

- Several new options and tools

Bad News

- Some may be difficult to use!

One example of subtle traps

- Symmetry of CSF: can be symmetric if geometry is defined by user (as in V63)
- Must be same as body if geometry is automatic
- Trimming can remove symmetry of body!

Another example of subtle traps

- If IRR=1 patch indices are defined by GDF and user
- If IRR=3 free surface patches are added by program after all other body patches (user inputs same as with IRR=0)
- Test 22 (FPSO with two tanks):
  IRR=0: NPTANK=(8-11) (12-15)
  IRR=1: NPTANK=(11-14) (15-18)
  IRR=3: NPTANK=(8-11) (12-15)

New features to be introduced in V6.3S

- Exact account of the free surface/body forcing
- Complete 2^{nd}-order effect in the internal tanks
- Option for using control surface for quadratic forces (2006). (Updated to correct evaluation of the vertical momentum flux)
- Optional B-spline approximation of the free surface forcing (2006)
- Option to shift input free surface field points away from the panel/patch boundaries (2007)

- Exact account of the free surface/body forcing

$$\begin{pmatrix}2\pi\\4\pi\end{pmatrix}\phi_S^{\pm}(\mathbf{x}) + \iint_{S_b}\phi_S^{\pm}G_{n_\xi}dS_\xi = \iint_{S_b}q_b^{\pm}GdS_\xi + \iint_{S_f}(q_s^{\pm}/g)GdS_\xi$$

At each node on S_f, $q_s^{\pm}$ are computed using ϕ and its derivatives, for a pair of frequencies, evaluated from

$$4\pi\phi(\mathbf{x}) = \iint_{S_b}\phi_n GdS_\xi. - \iint_{S_b}\phi G_{n_\xi}dS_\xi$$

- Complete 2nd-order effect in the internal tanks

new inputs

CFG:

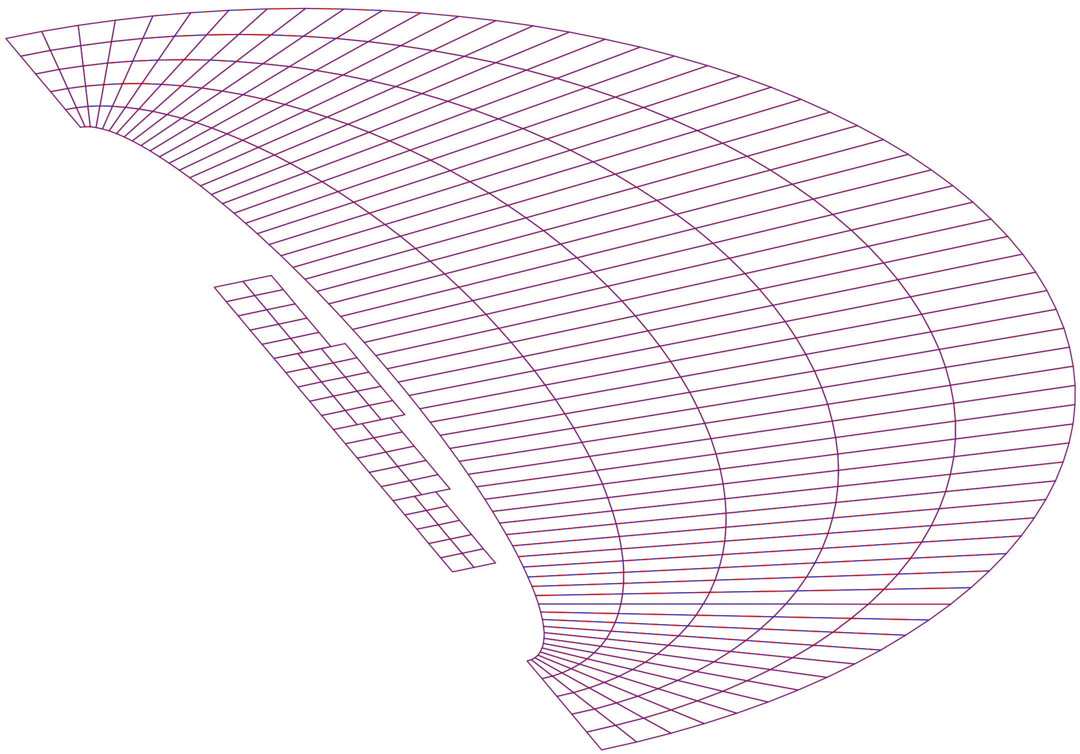
IPTANKFS=(N1,M1) (N2,M2)…(Nn,Mn)

Each tank free surface is described by contiguous patch/panel indices

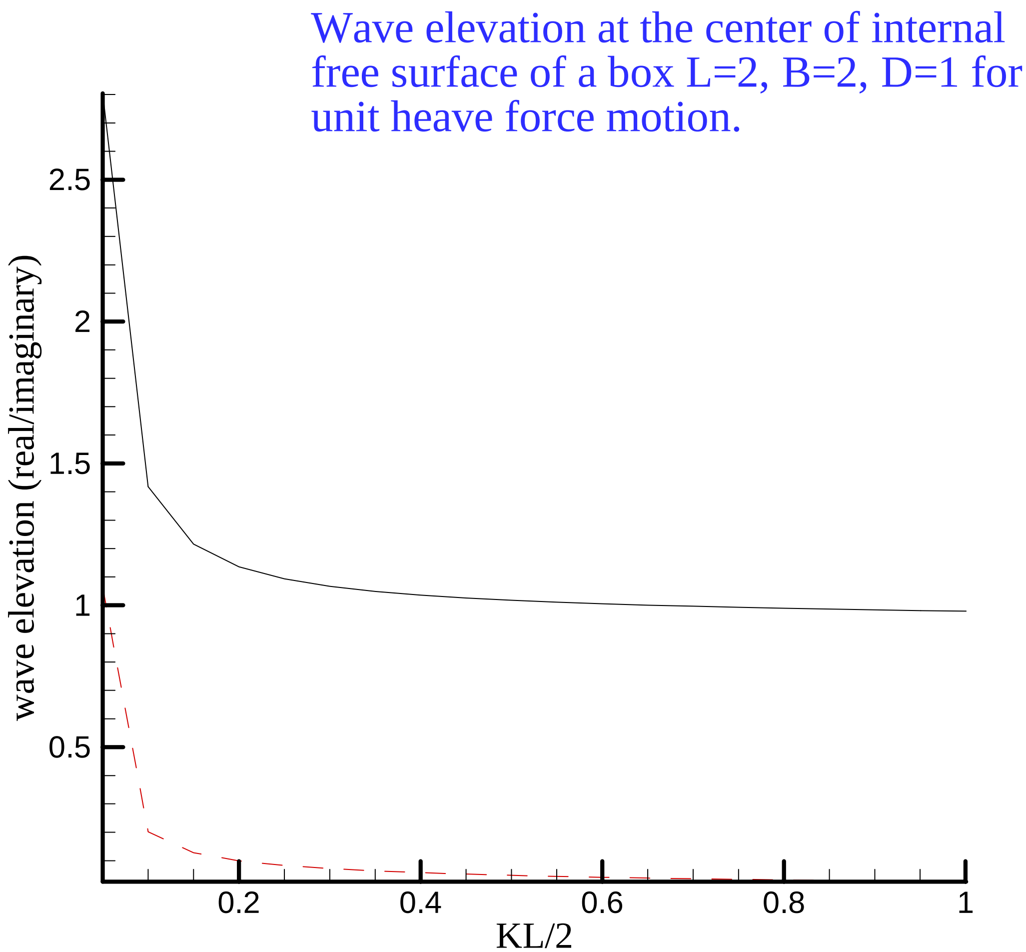
FDF:

Exterior and interior free surface patches/panels in global coordinates

4 internal tank free surface patches along with exterior free surface for an elliposoid. Input vertical coordinate of the patches can be arbitrary. The vertical coordinate of the exterior free surface is adjusted to 0 and those for internal tanks to ZTNK inside program (ie tank free surface relative to the exterior free surface)



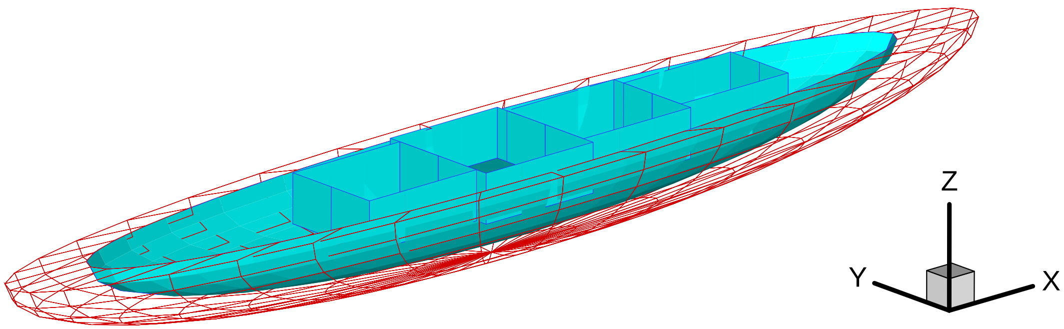
Low order method, using source formulation for field quantities, may not be accurate for internal flow.



- Option for using control surface for quadratic forces (2006). (Updated for correct evaluation of the vertical momentum flux)

Ellipsoid with internal tanks, length 300m, beam/draft 50m
Tank widthes varies: 24, 32, 40 m.

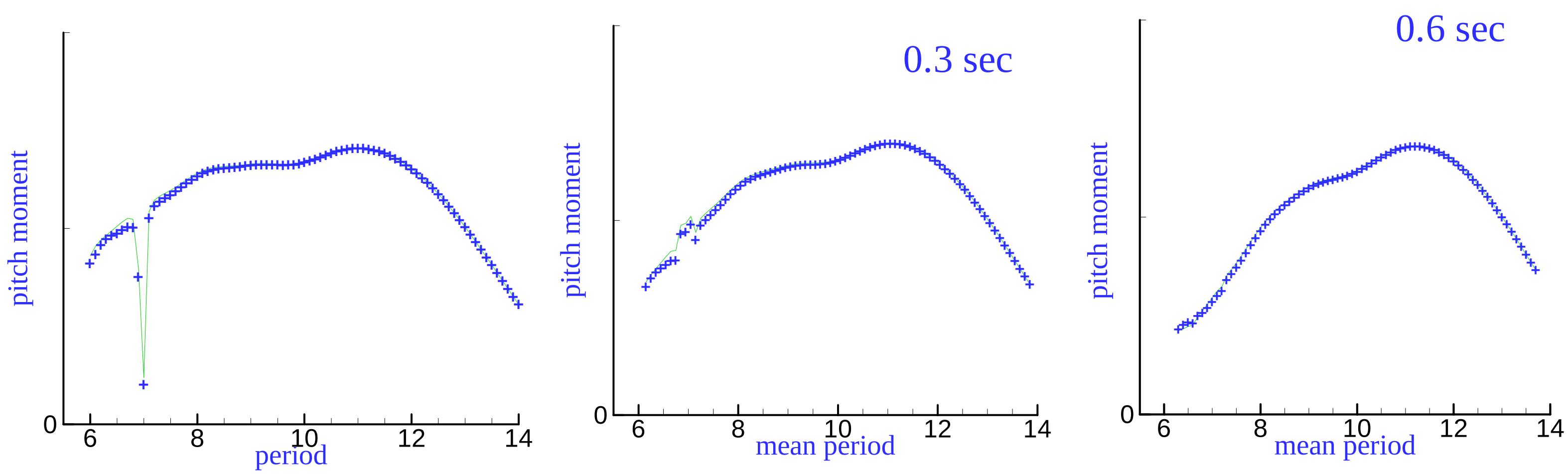
Red meshes represent ellipsoidal control surface 1.2 times the hull.



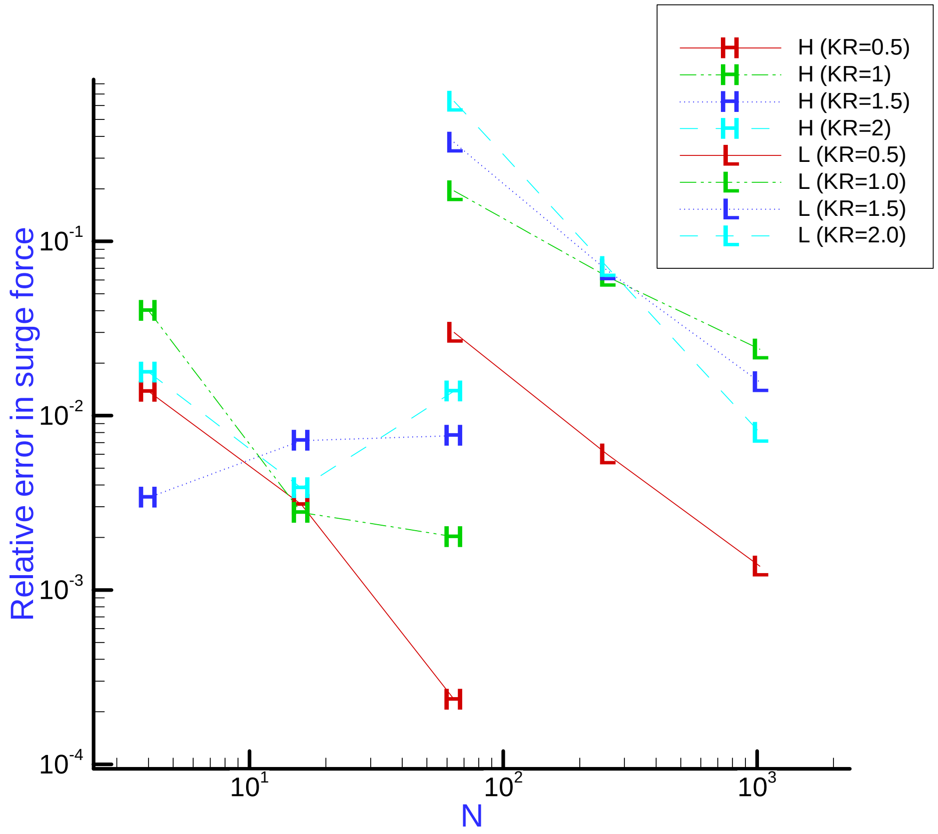
Control surface is used for external flow only. The pressure integration is used in internal tanks.

Pitch quadratic moment on an ellipsoidal hull with internal tanks for monochromatic and two pairs of bi-chromatic waves.

Lines by pressure integration and (+) using control surface



- Optional B-spline approximation of the free surface forcing (previous results)



Wavemakers and Absorbers

By J. N. Newman

Background and motivation

- Wavemakers and beaches are important elements of experimental wave basins
- Conventional beaches rely on viscous and nonlinear dissipation
- Suitably controlled wavemakers are effective as absorbers
- Analysis and optimization can be studied with linear potential theory

Havelock's (1929) Theory (2D, semi-infinite domain x>0)

$$\phi = \mathrm{Re}\left(\mathrm{i}\omega\xi_1\phi_1\mathrm{e}^{\mathrm{i}\omega t}\right)$$

$$\frac{\partial\phi_1}{\partial x} = Z(z) \quad \text{on} \quad x = 0$$

Solution: source distribution of density $Z(z)$ on $x = 0$

Free-surface elevation: $\zeta \simeq \xi_1 C_0 \mathrm{e}^{\mathrm{i}(\omega t - kx)}$

Hydrodynamic pressure force: $F_1 = -\omega^2 \left(a - \mathrm{i}b/\omega\right)\xi_1$

Wavemaker at x=0 in basin of length L (standing wave)

$$\zeta_s \simeq \xi_1 C_0 \left[\mathrm{e}^{\mathrm{i}(\omega t - kx)} + \mathrm{e}^{\mathrm{i}(\omega t - k(2L-x))} \right]$$

Wave absorber (j=2) at $x = L$:

$$\zeta_a \simeq \xi_2 C_0 \mathrm{e}^{\mathrm{i}(\omega t - k(L-x))}$$

Ideal absorber: $\quad \xi_2 = -\xi_1 \mathrm{e}^{-\mathrm{i}kL}$

$$\zeta_s + \zeta_a \simeq \xi_1 C_0 \mathrm{e}^{\mathrm{i}(\omega t - kx)}$$

Hydrodynamic pressure forces:

$$F_1 = -\omega^2 \left(A_{11}\xi_1 + A_{12}\xi_2 \right)$$

$$F_2 = -\omega^2 \left(A_{21}\xi_1 + A_{22}\xi_2 \right)$$

Time-Domain Analysis

Wavemaker velocity: $U(t)Z(z) \quad \text{on} \quad x = 0$

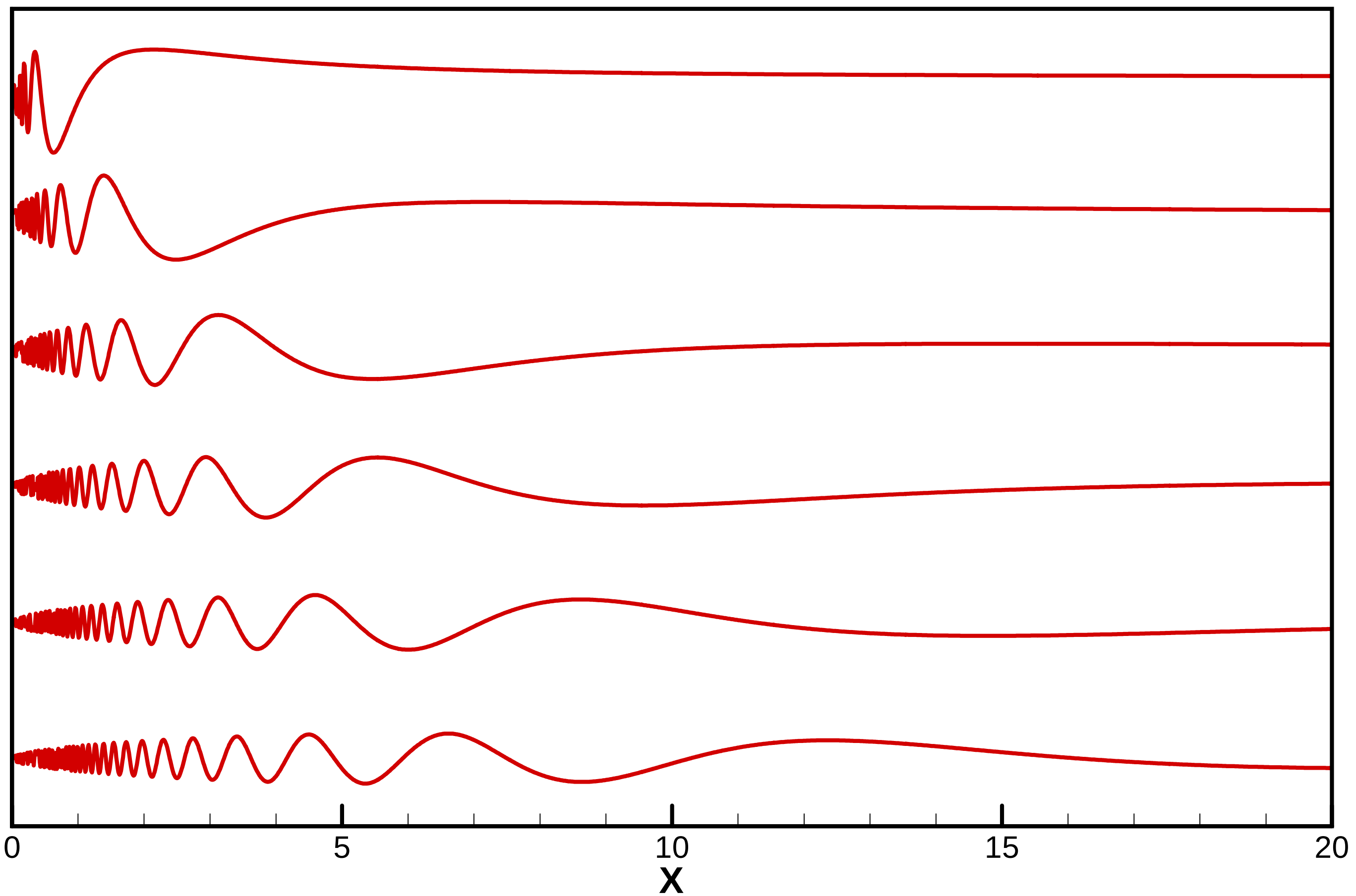
Solution: source distribution of density $U(t)Z(z)$ on $x = 0$

Free-surface elevation: $\zeta(x,t) = \int_0^t U(\tau)k(x,t-\tau)d\tau$

$$k(x,t) = -\frac{1}{\pi}\int_0^\infty \cos kx \cos\sqrt{gk}t \int Z(z)\mathrm{e}^{kz}dz dk$$

(cf. Wehausen & Laitone, 1960, eq. 13.54)

The impulse-response function k(x,t) for a hinged-flap wavemaker in deep water (hinge depth =2m, t=1 to 6 seconds)

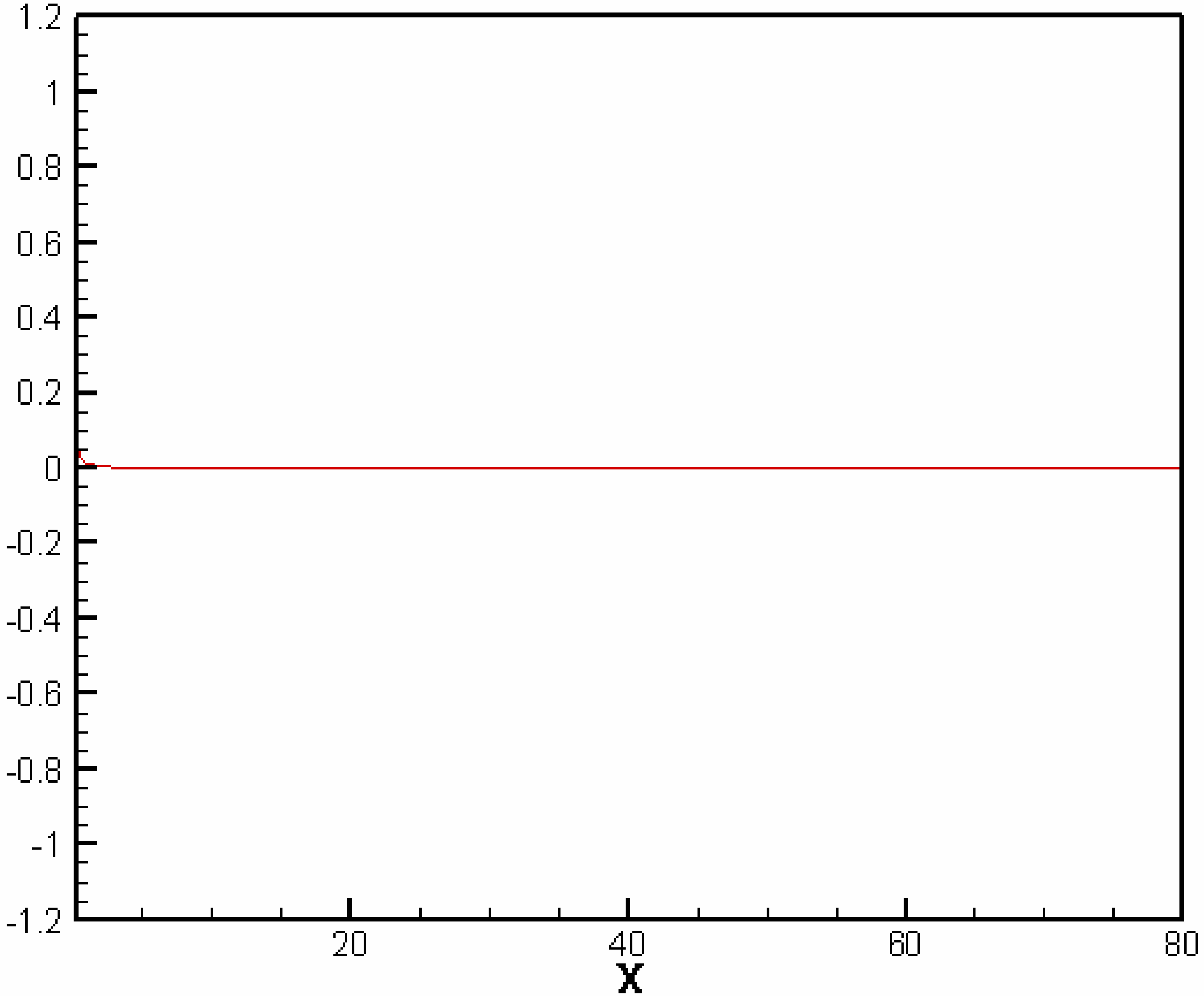


Numerical Simulations

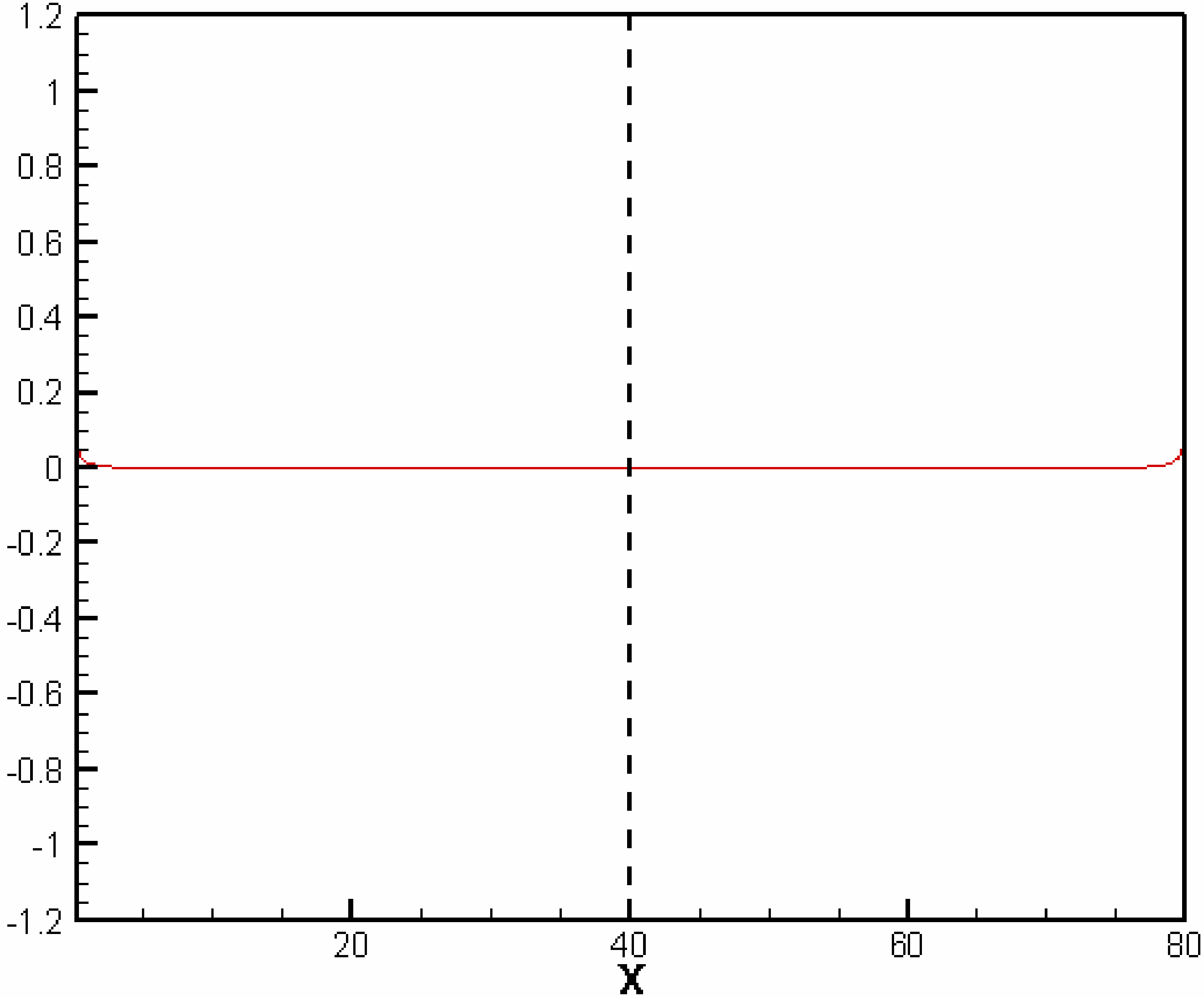
2-dimensional, time domain

$$U(t) = \sin \omega t \quad (t > 0)$$

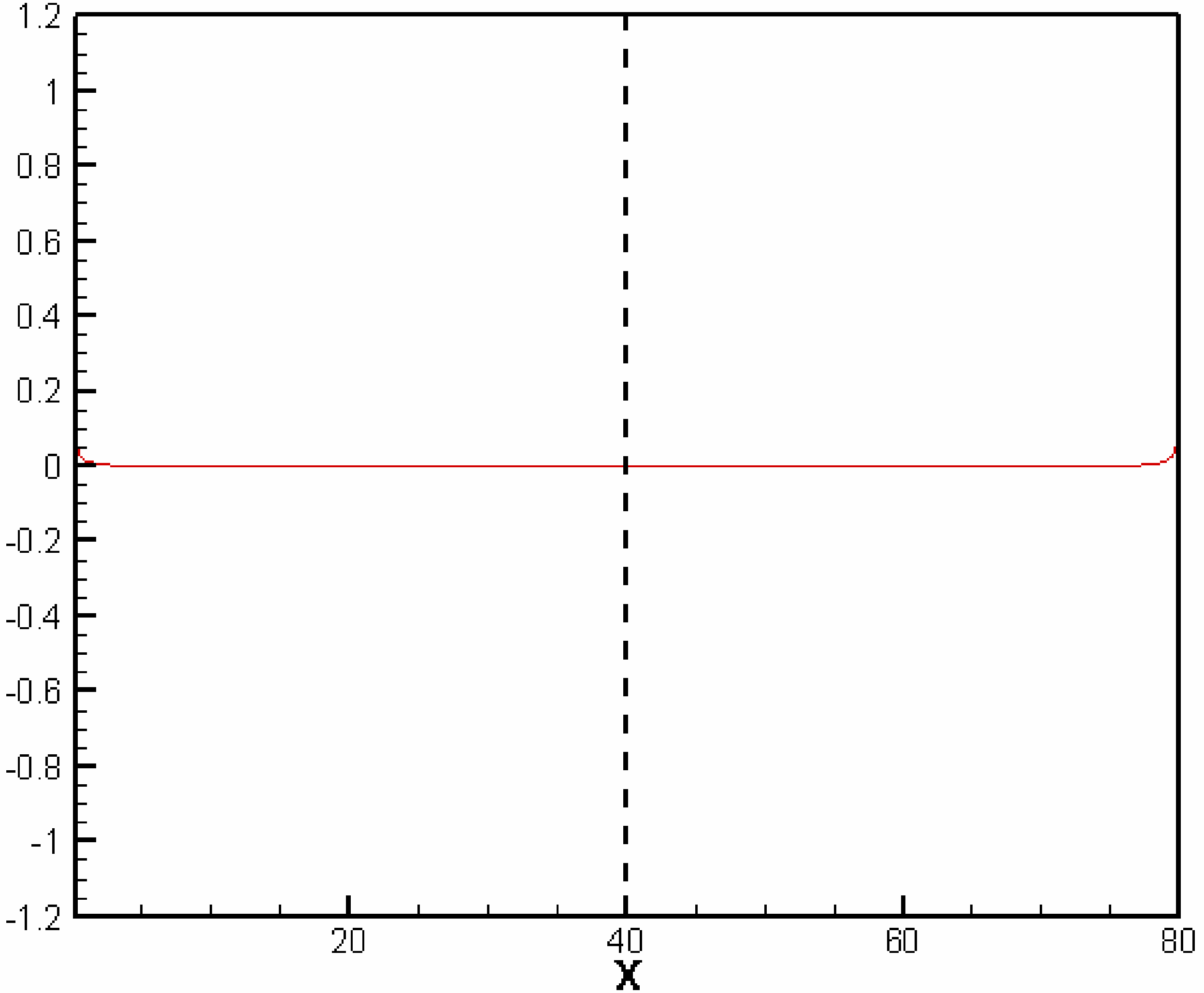
Wavemaker at X=0



Wavemaker at X=0 plus image at X=80



Absorber at X=40



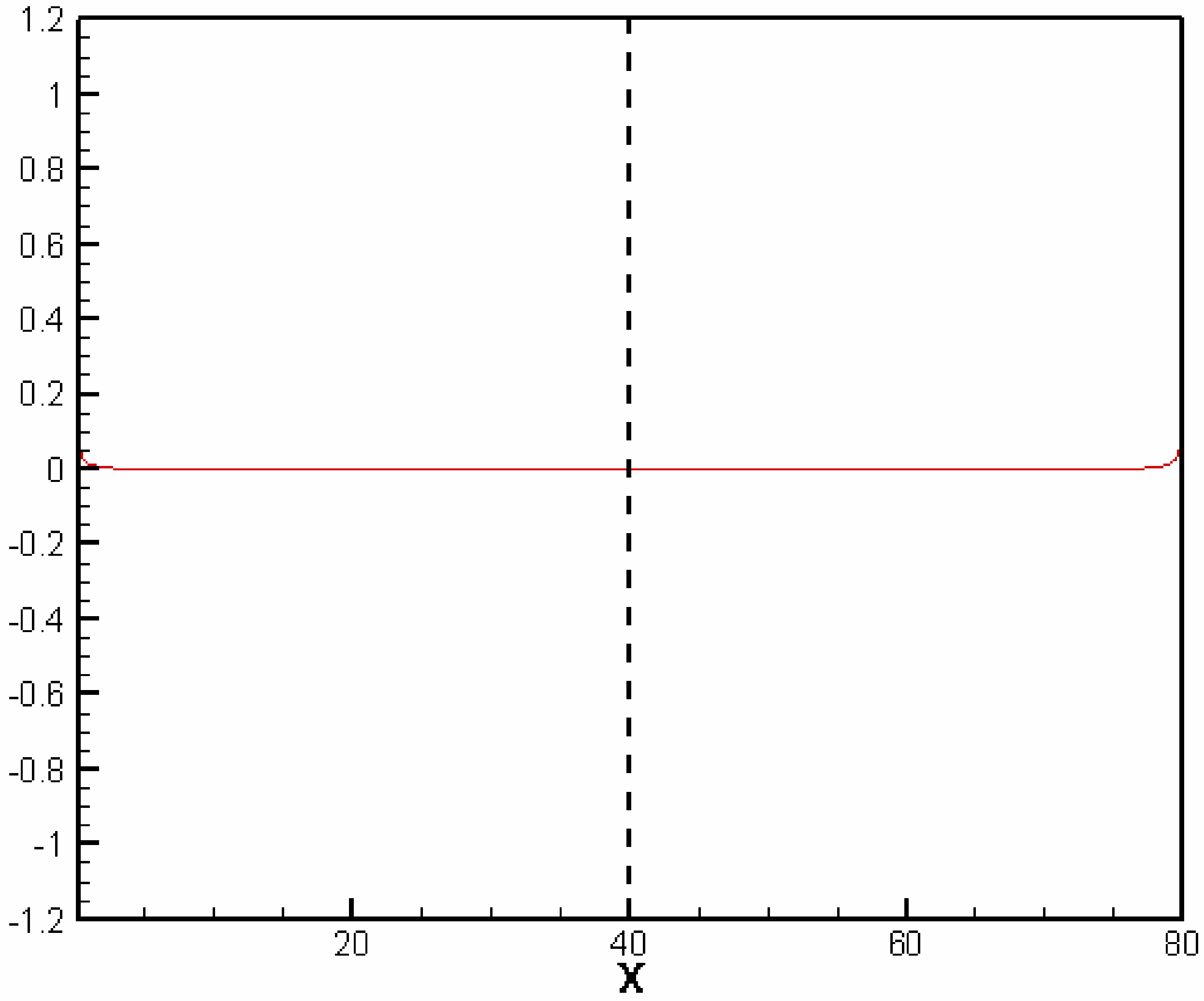
A better absorber:

$$\zeta_I(x,t) = \int_0^t U(\tau)k(x,t-\tau)d\tau$$

$$\zeta_A(x,t) = C\int_0^t \zeta_I(L,\tau)k(L-x,t-\tau)d\tau$$

(The coefficient C is evaluated numerically)

Better absorber at X=40



Numerical Simulations

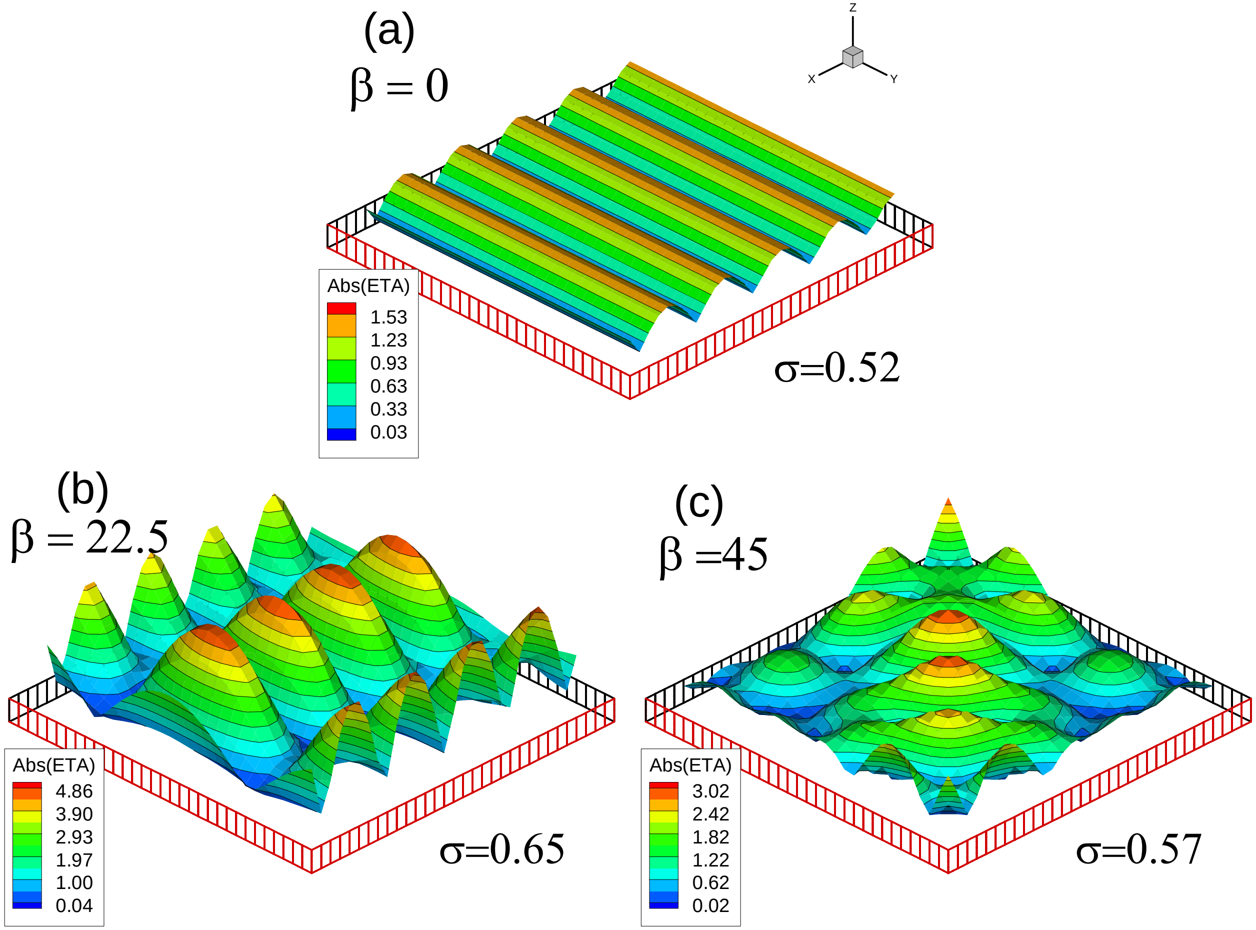
3 dimensional, frequency domain

(from panel code WAMIT)

Square tank – 16 m x 16 m x 2 m

128 wavemakers -- no absorbers (fixed)

N.B.: plots are of modulus, these are standing waves!
color scales are different in each plot



Absorber controller strategies

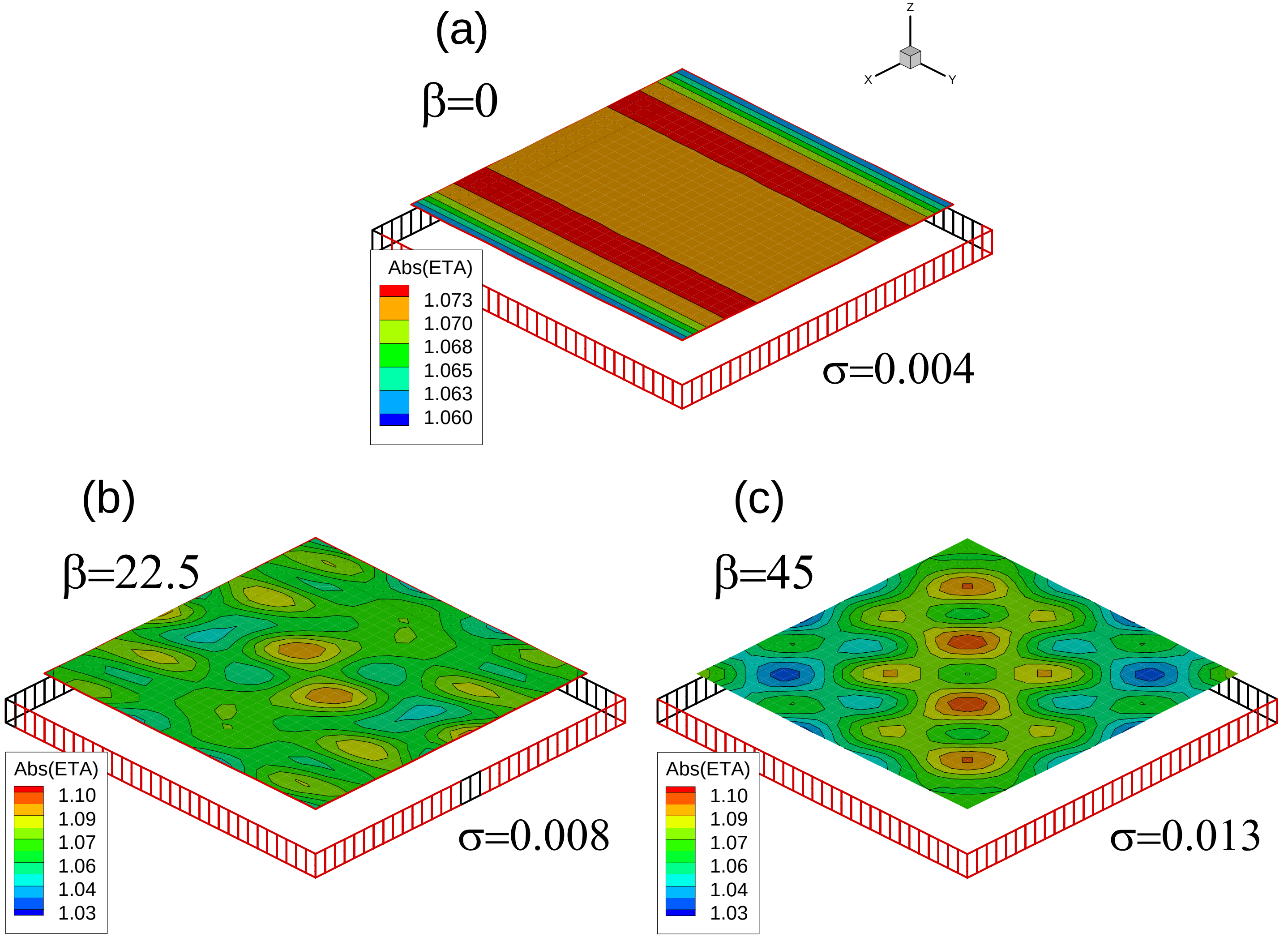
Kinematic Absorbers: $\mathrm{i}\omega\xi_j = \left(\frac{\partial}{\partial n}\right)\phi_I$

$$\xi_j = \left(n_x \cos\beta + n_y \sin\beta\right)\exp\left(-\mathrm{i}k(x_j \cos\beta + y_j \sin\beta)\right)$$

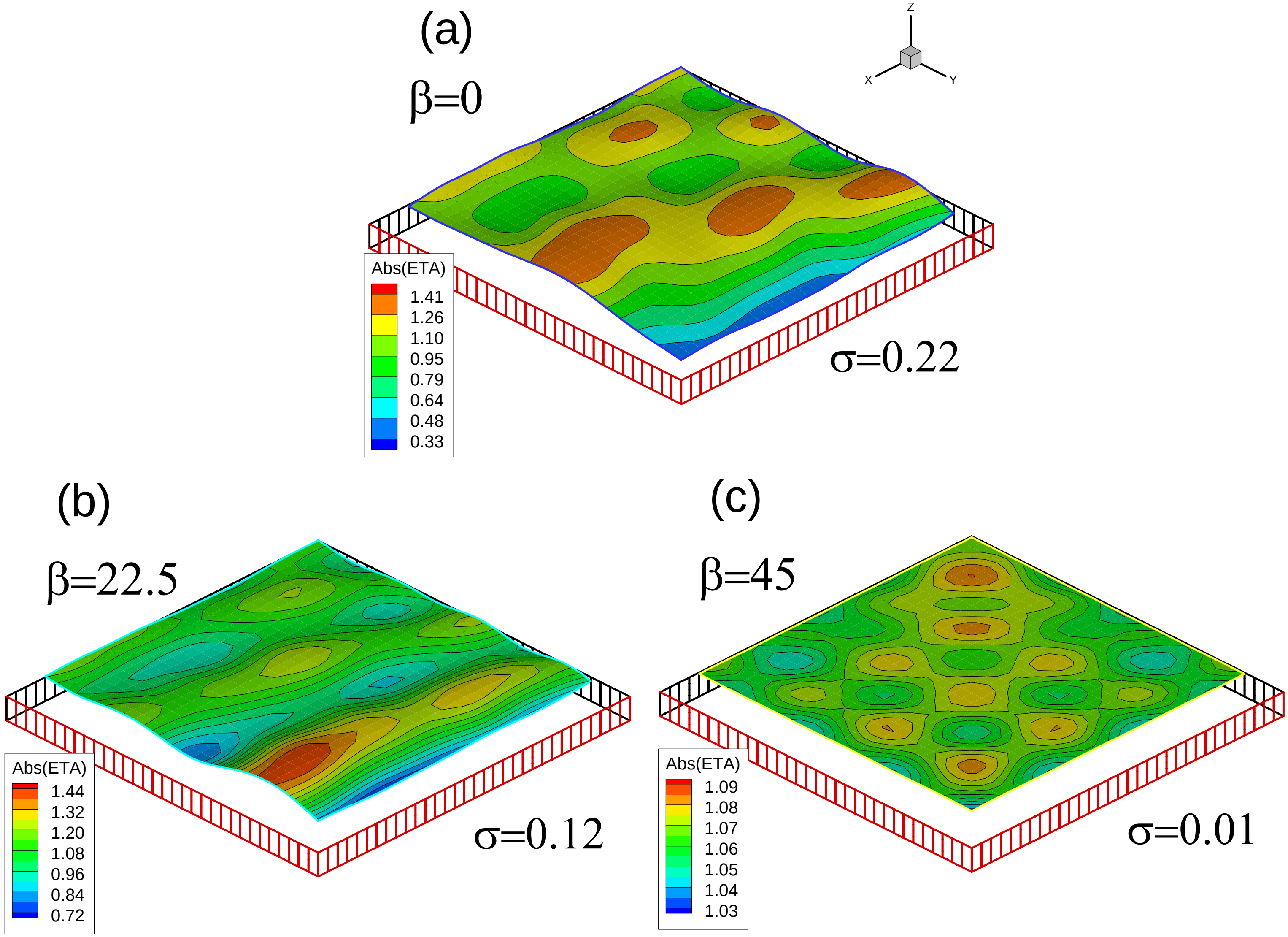
Dynamic Absorbers:

$$\sum_j A_{ij}\xi_j + \left(m_i' - \mathrm{i}b_i'/\omega\right)\xi_i = 0$$

Kinematic absorbers
(normal velocity same as progressive wave)

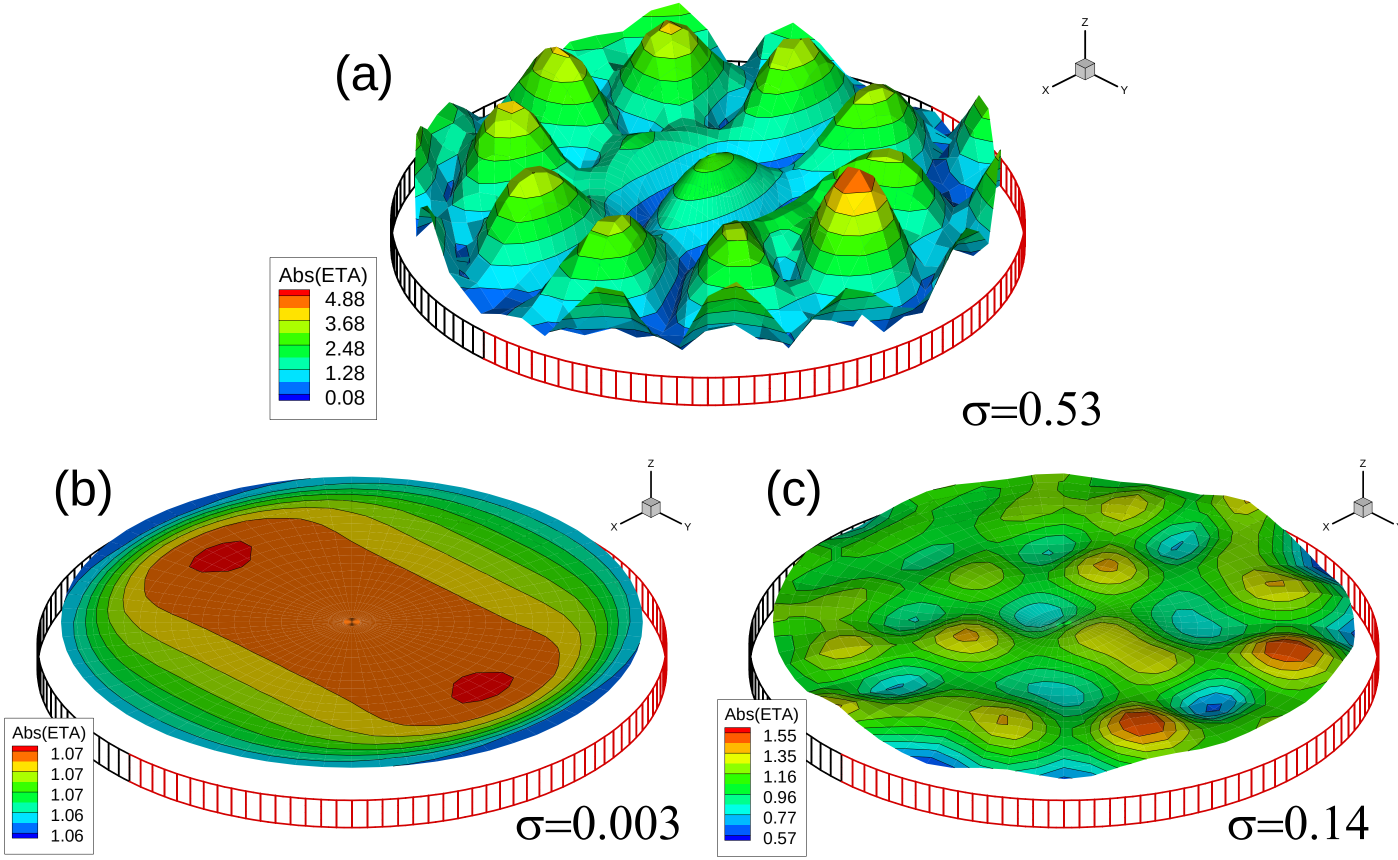


Dynamic absorbers



Circular tank – 10 m radius, 2 m depth
128 wavemakers (0.49 m width)

No absorbers

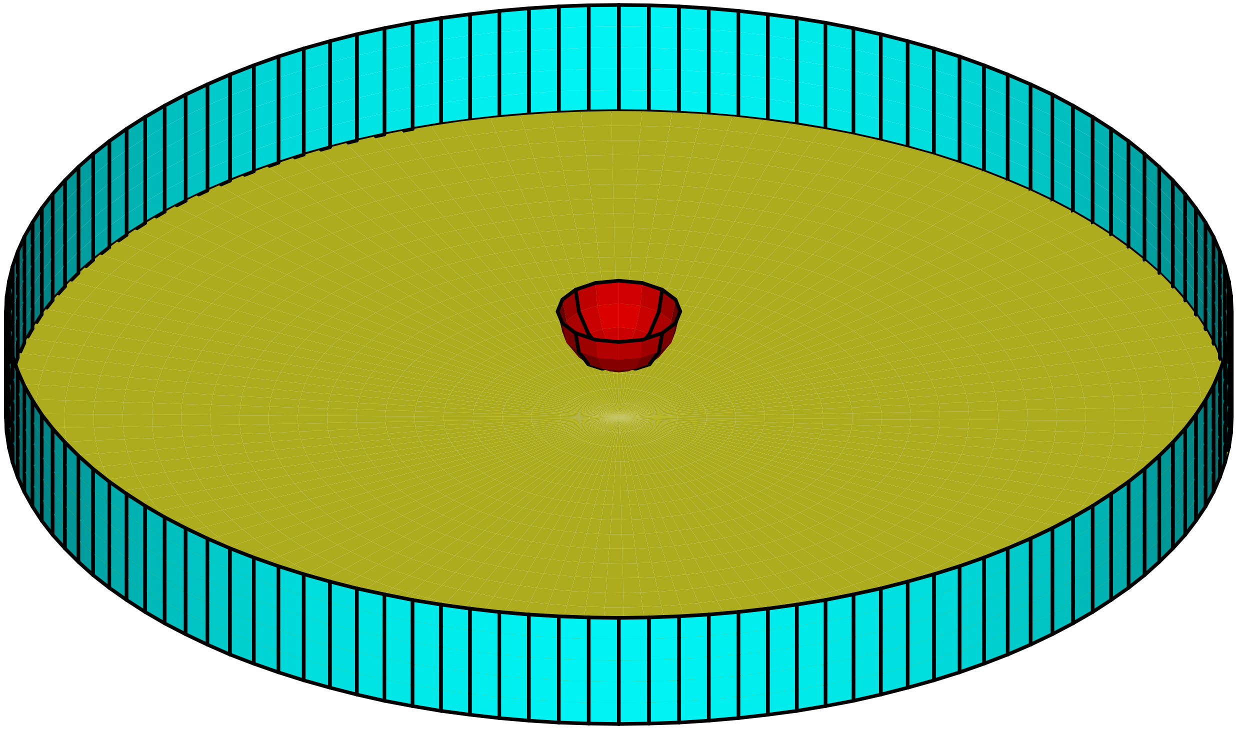


Kinematic absorbers

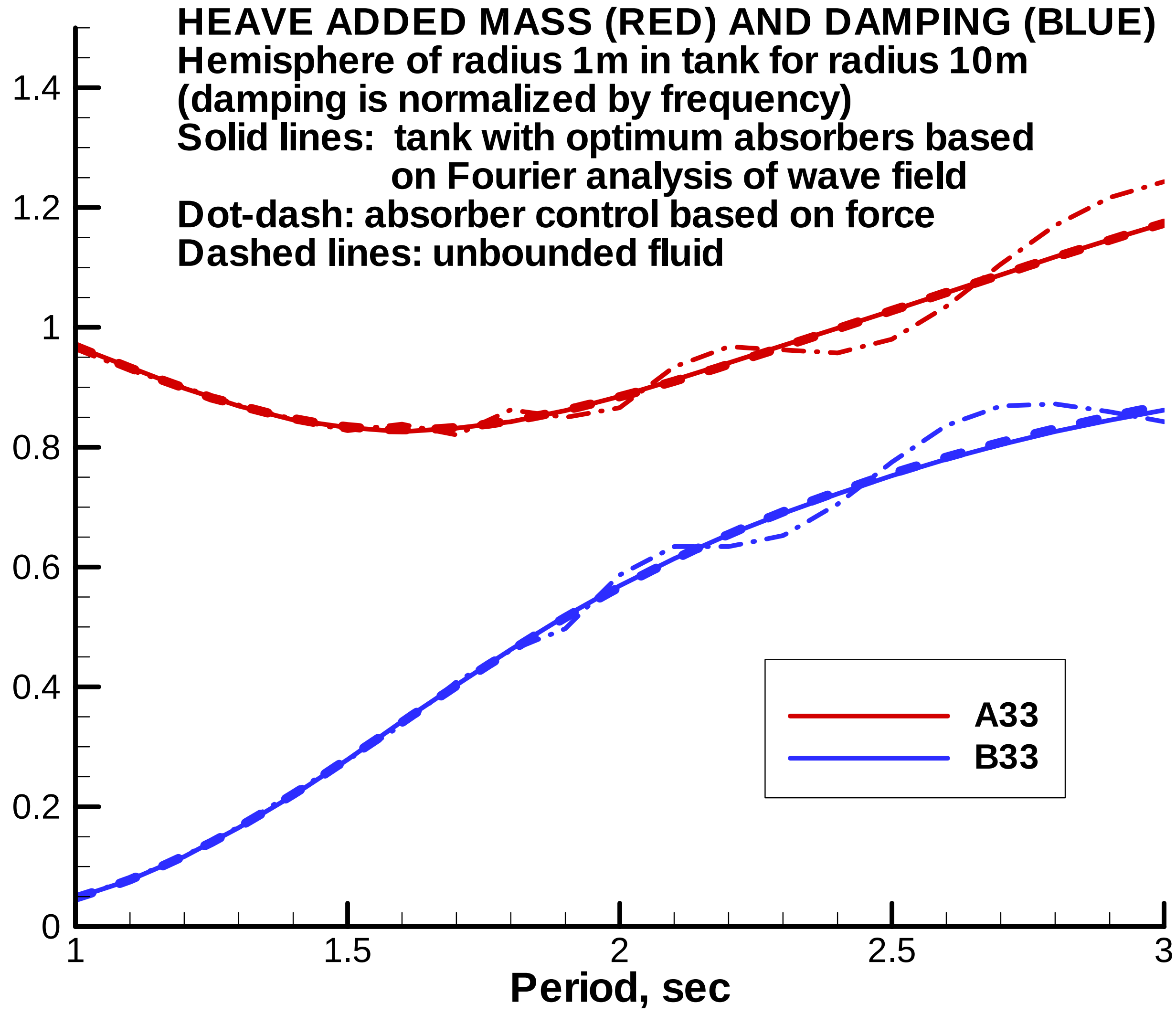
Dynamic absorbers

Circular wave tank of radius 10m, depth 2m, 128 wavemakers

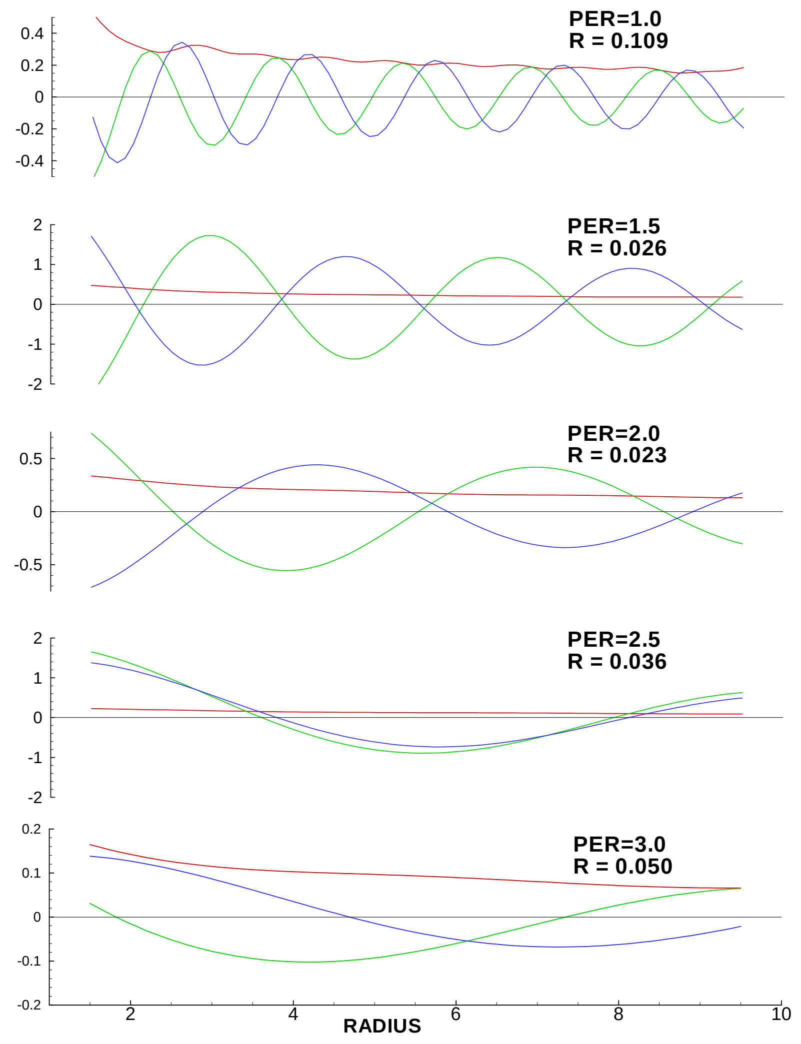
Floating hemisphere in center of tank, radius 1m



Heaving hemisphere in center of a round tank with absorbers

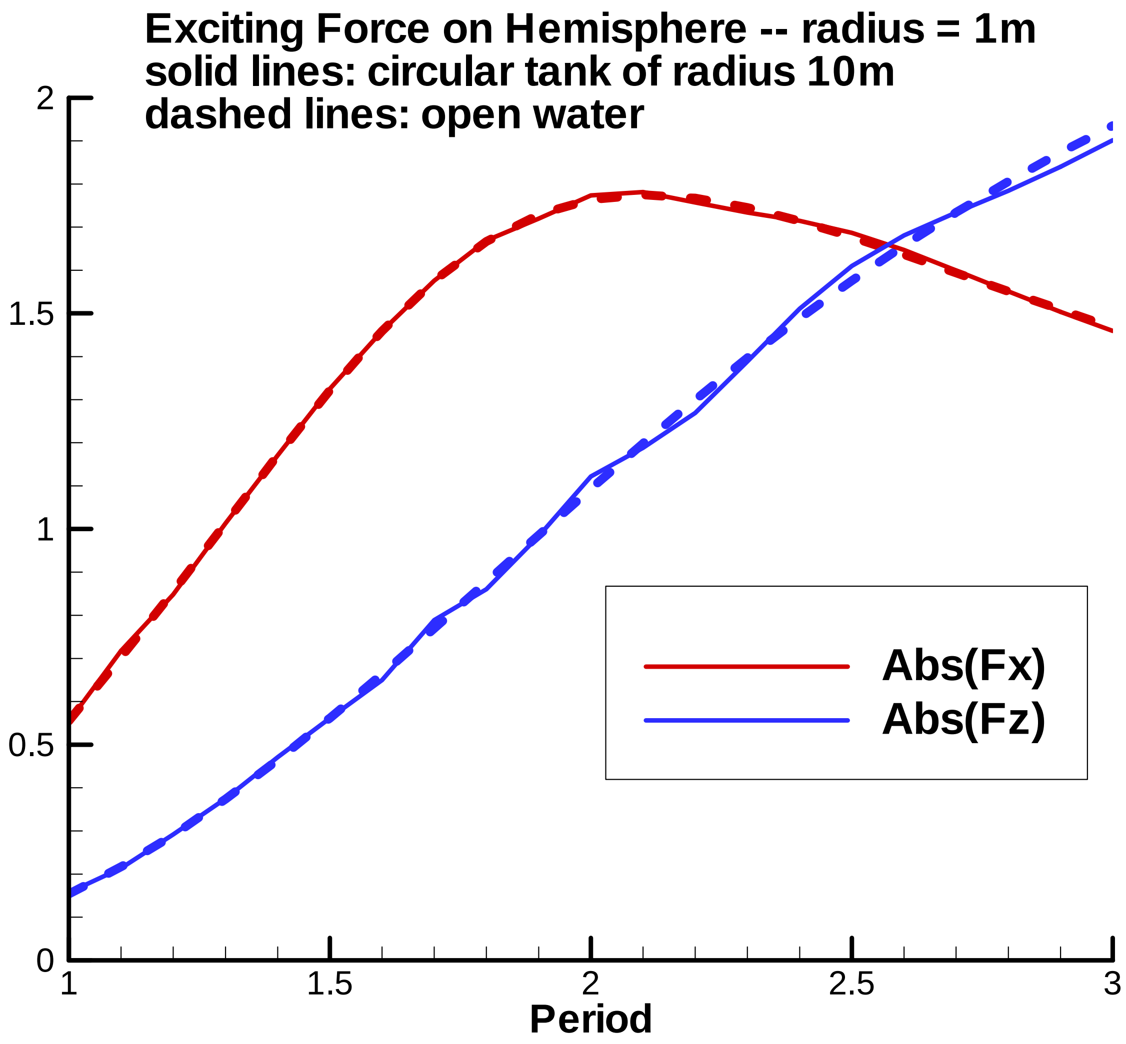


Standing waves from heaving sphere, absorbing wavemaker and waves radiated by sphere



(Wavemaker amplitude reduced by 1/10)

Surge/heave exciting forces in progressive waves



Dynamic absorbers with scatterering

(all wavemakers are absorbers)

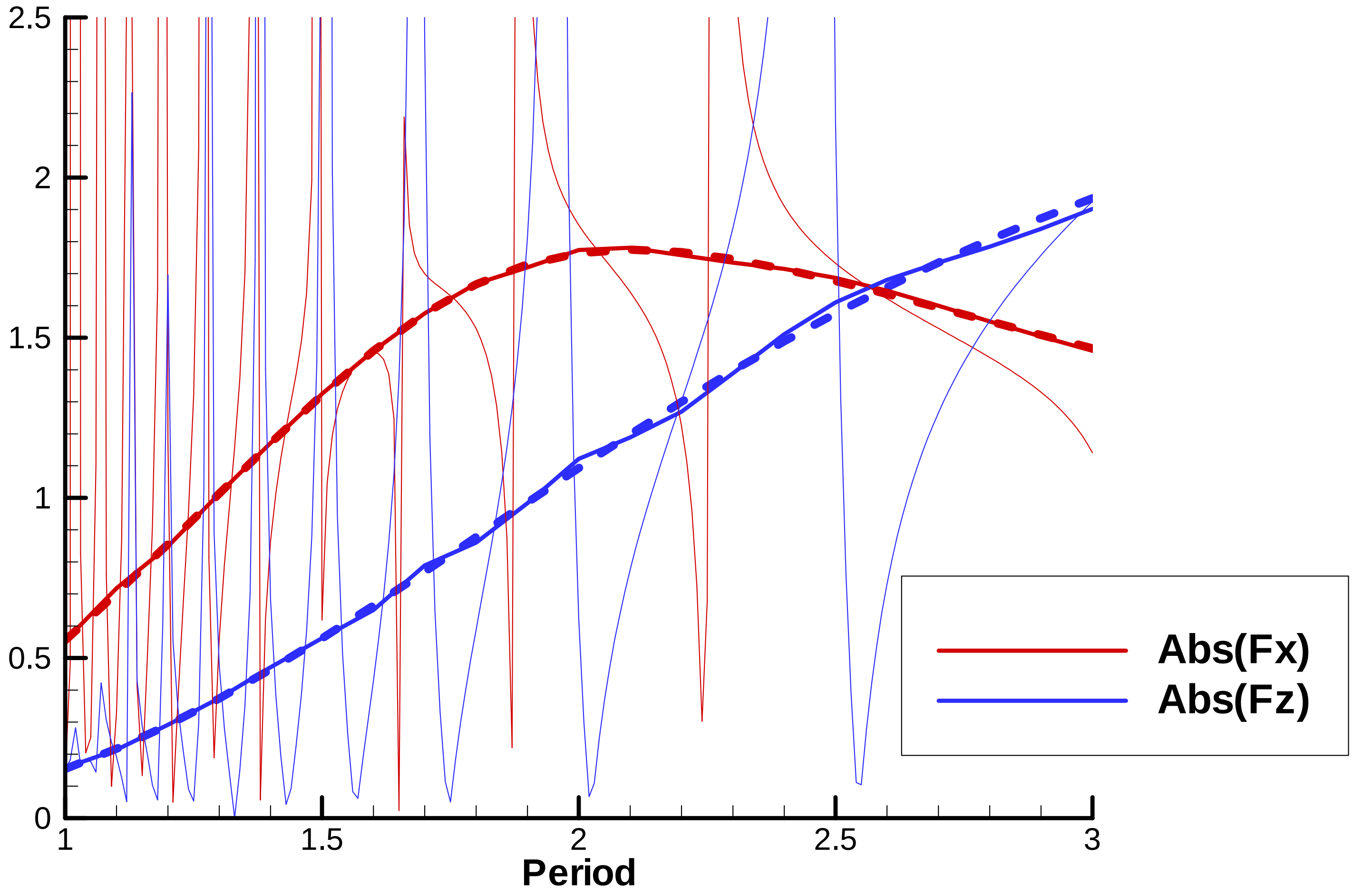
$$\tilde{\xi}_j = \frac{1}{\mathrm{i}\omega}\frac{\partial \phi_I}{\partial n} \quad \text{(optimum without scatterers)}$$

$$-\omega^2 \left(\tilde{A}_{ij} - (a + \mathrm{i}b/\omega)\delta_{ij}\right)\tilde{\xi}_j = 0$$

$$\xi_j = \tilde{\xi}_j + \xi'_j$$

$$-\omega^2 \left(A_{ij} - (a + \mathrm{i}b/\omega)\delta_{ij}\right)\xi'_j = \omega^2 \left(A_{ij} - \tilde{A}_{ij}\right)\tilde{\xi}_j$$

Comparison of exciting forces with/without absorbing scattered waves



CONCLUSIONS

- With suitable controls it is possible to get nearly complete wave absorption in 2D
- 3D effects are important, especially oblique incidence on the absorbers
- Absorbing scattered/radiated waves is essential
- Developing effective absorbers is a challenging problem
- Linear frequency-domain results are idealized, (may represent an upper bound on performance)

Current Participants

Chevron

ConocoPhillips

OTRC

Petrobras/USP

Shell

StatoilHydro

Donald Danmeier
Chevron Energy Technology Co.
6001 Bollinger Canyon Road
Room L-4220
San Ramon, CA 94583-2324
DDanmeier@chevron.com

Marcos Ferreira
Petrobras SA
Eng. Marcos Donato Ferreira
CENPES/PDP/MC
Av Horacio Macedo, 950
Cidade Universitaria, Ilha do Fundao
21941-915
Rio de Janeiro, Brazil
marcos.donato@petrobras.com.br

Stergios Liapis
Shell Oil Company
Offshore Structures
3737 Bellaire Blvd.
Houston, TX 77025
Phone) 713 245 7677
stergios.liapis@Shell.Com

Chang-Ho Lee
WAMIT
822 Boylston Street, Suite 202
Chestnut Hill, MA 02467
chlee@wamit.com

Rick Mercier
Offshore Technology Research Center
1200 Mariner Drive
College Station, TX 77845-3400
rmercier@civil.tamu.edu

Nick Newman
WAMIT
1 Bowditch Road
Woods Hole, MA 02543
jnn@mit.edu

John Niedzwecki
Offshore Technology Research Center
1200 Mariner Drive
College Station, TX 77845-3400
j-niedzwecki@tamu.edu

Robert Page
AeroHydro
54 Herrick Road/PO Box 684
Southwest Harbor, ME 04679-0684
robertpage@aerohydro.com

Amal C. Phadke
ConocoPhillips Company
600 N Dairy Ashford Rd, Office OF1098
Houston, TX 77079
amal.c.phadke@conocophillips.com

Chad Petrash
ConocoPhillips Company
600 N Dairy Ashford Rd
Houston, TX 77079
chad.petrach@conocophillips.com

Sam Ryu
R&D SOFEC Inc.
14741 Yorktown Plaza Dr.
Houston, TX 77040
sam.ryu@sofec.com

Joao Sparano
University of Sao Paulo
Department of Naval Architecture and Ocean Engineering
2231, Av. Prof. Mello Moraes
Cidade Universitaria
Sao Paulo, SP, Brazil CEPO05508-900

Xuemei Zhu
WAMIT Inc.
17 Berch Ct.
Wilton, CT 06897
xmzhu@wamit.com

Per Teigen
StatoilHydro
Postuttak
N 7005 Trondheim
Norway
pte@statoilhydro.com

Street Address
Ark, Ebbels v.10
Rotvoll
Trondheim, Norway

John Letcher
AeroHydro
54 Herrick Road/PO Box 684
Southwest Harbor, ME 04679-0684
jletcher@aerohydro.com

Rune Yttervik
StatoilHydro ASA
Research Centre, Bergen
Norway
Rune.Yttervik@statoilhydro.com

Tim Finnigan
Chevron Energy Technology Co.
6001 Bollinger Canyon Road
Room L-4296
San Ramon, CA 94583-2324
TimFinnigan@Chevron.com

Shihwei Liao
ConocoPhillips
OF 1084, T & MP
600 North Dairy Ashford
Houston, TX 77079
Shihwei.Liao@conocophillips.com

Finn Gunnar Nielsen
StatoilHydro ASA
PO Box 7190
N-5020 Bergen, Norway
Finn.Gunnar.Nielsen@statoilhydro.com

Street Address
Sandsliveien 90
N-5254 Sandsli, Norway

Kazuo Nishimoto
Kazuo Nishimoto, Prof. Dr.
Department of Naval Architecture & Ocean Engineering
EPUSP
Numerical Offshore Tank - TPN
Av. Prof. Mello Moraes, 2231, Cidade Universitária
CEP05508-900, SP, SP, Brazil
knishimo@usp.br