HAWASSI-AB

User Manual
(Analytic Ship)

by

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Preamble

Waves are fascinating, important and challenging.
The importance can be substantiated from some well-known observations:

- Half of the world population lives less than 150 km from the coast
- The sea is a relatively easy medium for transport of people and goods (half of all the world crude oil and increasingly more natural gas) and for intercontinental telecommunication through cables
- Ocean resources of food and minerals are only at the start of discovery, profits from wind parks and harvesting of wave energy in coastal areas is expanding.

Therefore, a sustainable and safe development of the oceanic and coastal areas is of paramount importance. Nowadays that means that for the design of harbours, breakwaters and ships, calculations are performed with increasingly more accurate and fast simulation tools. Tools that are, packaged in software, based on the basic physical laws that describe the properties of waves, the wave-ship interaction, the forces on structures, etc.

HAWASSI software is aimed to contribute to extend the accuracy, capability and speed of existing numerical methods and software using applied-mathematical modelling methods that are at the basis.
A basis with a rich history that is fascinating and challenging. Starting in the 18th century with Euler who generalized Newton's law for fluids, in the 19th century Airy 'solved' the problem to describe small amplitude surface water waves. In that same century, many renowned scientists like Scott Russel, Stokes, Boussinesq, Rayleigh and Korteweg & De Vries investigated the nonlinear aspects of finite amplitude waves. As much as possible without the need to fully calculate the internal fluid motion; started with Boussinesq in an approximative way, this was formulated accurately in the 1960-1970's by Zakharov and Broer by providing the Hamiltonian form of the dynamic equations.
HAWASSI software is based on these last findings, with methods for making the principal description into a practical (numerical) modelling and implementation tool.

The first release of the software deals with wave propagation, but the developers are in the process to extend the capabilities to include coupled wave-ship interactions, amongst others, in later releases.
We sincerely hope that the use of the software, just as the design of it has been, will be fascinating and challenging for students and academicians as well as for practitioners; from both groups we hope to receive comments and suggestions for further improvements and extensions in a way that can be profitable for both sides.

Let nature tell its secrets
Listen to the physics in its mathematical language
Restrain from idealization
Only then models will serve us in abundance

The software has been developed over the past years in collaboration with the University of Twente, Netherlands, with additional financial support of Netherlands Technology Foundation STW and Royal Netherlands Academy of Arts and Sciences KNAW.

1 Introduction

This document is a manual of analytic ship module that serves as a guide for using and running the module. Anaytic ship module solves diffraction, radiation problem and response amplitude operator (RAO).

Section 2 describes briefly the underlying modelling method in solving diffraction, radiation and RAO.
Section 3 describes graphical user interface for this module.
Section 4 shows results from 7 testcases.

2 Description of Analytic Ship Module

This section gives brief description of analytic formulation for solving diffraction, radiation problem and for calculating Response Amplitude Operator (RAO).

2.1 Diffraction and radiation modules

Diffraction module is for solving wave-fixed (sectioned) ship interaction problem. In this module excitation wave forces, reflection and transmission coefficients are calculated for given input harmonic waves parameter (Amplitude, Periode) and ship section geometry.
Radiation module is for solving radiation problem in which ship is oscillating and generates radiated waves in still water. In this module added mass, damping coefficients and generated wave amplitude are calculated for given ship section geometry and harmonic wave period/frequency.

Underlying Modelling Methods

Diffraction and radiation modules are based on the following principles

- The free surface dynamics for inviscid, incompressible fluid in irrotational motion satisfying Laplace condition, kinematic surface condition, bottom condition. For diffraction, the fluid potential at ship hull satisfies ship impermeable condition ($\partial_{\boldsymbol{n}}\Phi=0$) and for radiation ($\partial_{\boldsymbol{n}}\Psi = \boldsymbol{\nu}$) where $\boldsymbol{n}$ is unit normal vector at ship hull, $\boldsymbol{\nu} = (\boldsymbol{n}, \boldsymbol{n} \times \boldsymbol{r})$ is generalized unit normal vector at ship hull and Ψ is normalized radiation potential.

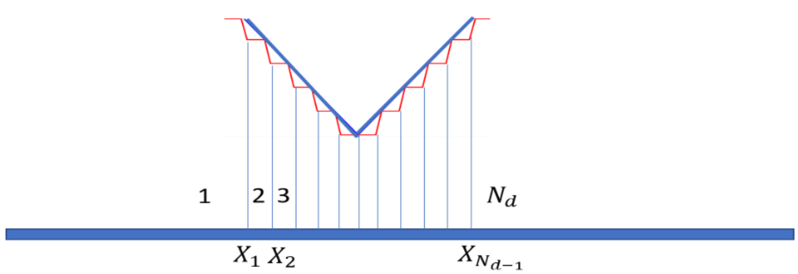


Figure 1 Domain division (dotted-lines) and approximated ship hull (red)

- The analytic solution is solved using eigen-function expansion as in (Sulisz, 93) for diffraction problem and as in (Zhang, 04) for radiation problem but extended for arbitrary ship form. The arbitrary ship form is approximated with step method as in figure 1.
- The solution is described by anzats of linear fluid potential in N_d domains and expanded for N_{ev} evanescent term.
- The continuity and flux condition at domain boundaries $(X_1, X_1, \cdots, X_{N_d-1})$ are applied and lead to system of equations of $2 \times (N_d - 1) \times (N_{ev} + 1)$.
- Then final solution of potential in each domain is defined after solving the system of equations.
- The output of diffraction module are excitation forces (sway, heave) and moment (roll) , reflection, transmission coefficients. The output for radiation module are added masses, damping coefficients and generated wave amplitude.

2.2 RAO module

RAO module gives response amplitude of sway, heave and roll motion for given excitation wave forces, added masses and damping coefficients. The RAO calculation can be done only if data of excitation forces, added masses and damping coefficients are available.

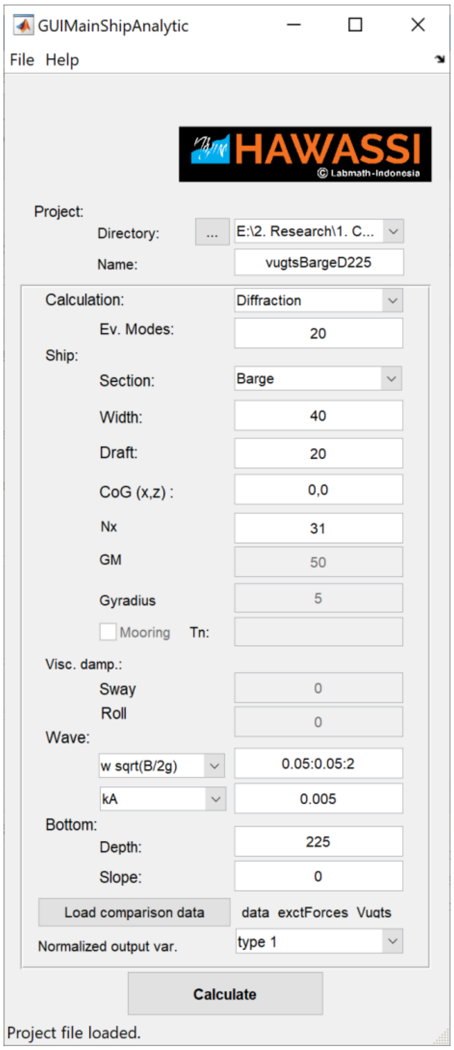
The RAOs are calculated based on following principles:

- Spring mass system both for coupled and uncoupled motions.
- External forces are excitation wave forces that obtained from diffraction calculation.
- Added masses and damping coefficients are obtained from radiation calculation.
- Mass are calculated from area of ship hull below still water level. Moment of inertia are calculated for given user input of gyradius.
- Restoring forces are calculated for each motion. If user apply mooring effect by changing natural period, the restoring forces will be adjusted. Default values for restoring force coefficients with g gravity, B ship width, m ship mass and $\overline{GM}$ metacenter height are $C_{22} = 0, C_{33} = gB, C_{44} = mg\overline{GM}$ for sway, heave, roll respectively.
- Viscous damping term are applied for given user input drag coefficients (C_d).
  The sway damping term are expressed with ρ mass density, T ship draft, $\dot{Y}$ sway motion velocity as
  $F_{v_2} = -\frac{1}{2}\rho C_{d_2} T\dot{Y}|\dot{Y}|$,
  and for roll are expressed with $\dot{\theta}$ roll angular velocity, C_{d_4}drag coefficients in scale 0.1-0.2 as
  $F_{v_2} = -\frac{1}{2}\rho C_{d_4} B^4\dot{\theta}|\dot{\theta}|$.

3 GUI's of Analytic ship module

3.1 Input panel

For ease of operation, Analytic ship module includes Graphical User Interfaces (GUI), as input-output managers.



The GUI will be described briefly in this sections. The meaning of most required input fields needs no or little explanation; the choices that can be made will be described. The function of, and required input format for input panels is indicated when the cursor is moved over it.

For starting a project, choices to create a new project or to load an existing project are in **Start Page GUI**. For creating a new project, push 'New Project' button and choose 'Analytic – Wave Ship' then fill in the project name and browse a project directory, after that the **GUMainShipAnalytic** will be shown. For load an existing project, if the project is available in the project historical table, choose the project and then push 'Open Project', otherwise browse a project file 'abprojSA_ProjectName'.

GUIMainShipAnalytic

Opening ***File*** will show

New Project: to go to the start page GUI to choose 'project' that has been created before (including the provided test cases) from which data can be loaded to be inserted in the GUI or to create a new project.

Opening ***Help*** will show manual of this module.

The ***Project Directory*** can be chosen and specified; the software will create a new folder named as you specified in '***Project Name***', if the project directory does not contain this folder yet; if the folder already exists, it will keep and use it.

ALL output of a simulation will be stored in this subfolder.

Input panel contains several group input:

- ***Choices of calculation***
- ***Ship***
- ***Viscous damping***
- ***Wave***
- ***Bottom***
- ***Comparison data***
- ***Choices of normalized output variables***

After '***Calculate***', during the calculation a time-indicator estimates the remaining time.
After calculation finished, output will be shown in figures and data will be saved in the working directory folder \ ***Project Directory\ 'Project Name'\.*** The project will be saved in the folder with name 'abprojSA_ProjectName'. After diffraction calculation, unnormalized forces are saved in 'datCalForces', refltection and transmission coefficients are saved in 'datCalReflTrans'. After radiation calculation, unnormalized added mass is saved in 'datCalAddedMass', damping coefficients in 'datCalDampCoef', and radiated wave amplitude in 'datCalRadWaveAmpl'. After RAO calculation, RAOs of uncoupled motion are saved in 'datCalRAO' and for coupled motion in 'datCalRAOCM'.

Choices of normalized output variables are as follows

1. Diffraction
   The output variables are normalized, with B ship width, T ship draft, $A = BT$, $b = B/2$, D still water depth, a incoming wave amplitude, ka wave steepness, as follows

Var/type	1	2	3	4	5
$\bar{F}_x$	$F_x/gAka$	F_x/gTa	F_x/gTa	F_x/gBa	F_x/gDa
$\bar{F}_z$	F_z/gBa	F_z/gBa	F_z/gba	F_z/gBa	F_z/gDa
$\bar{M}_\theta$	$12M_\theta/gB^3ka$	$M_\theta/gBTa$	$M_\theta/gbTa$	M_θ/gB^2a	M_θ/gD^2a

2. Radiation
   Added mass ($\boldsymbol{A_{jk}}$) and damping coefficients $\boldsymbol{B_{jk}}$, for all motion direction, sway (2), heave (3) and roll (4), are normalized as follows
   Type 1:

$$\boldsymbol{\bar{A}_{jk}} = \begin{matrix} \boldsymbol{A_{jk}/\rho A} \\ \boldsymbol{A_{jk}/\rho AB} \\ \boldsymbol{A_{jk}/\rho AB^2} \end{matrix} \;;\; \boldsymbol{\bar{B}_{jk}} = \begin{matrix} \boldsymbol{(B_{jk}/\rho A)\sqrt{B/2g}} & \boldsymbol{j = 2, 3, k = 2, 3} \\ \boldsymbol{(B_{jk}/\rho AB)\sqrt{B/2g}} & \boldsymbol{j = 4, k = 2, 3 \text{ or } j = 2, 3, k = 4} \\ \boldsymbol{(B_{jk}/\rho AB^2)\sqrt{B/2g}} & \boldsymbol{j = 4, k = 4} \end{matrix}$$

   Type 2: Added masses are same as in type 2m but the damping coefficients are

$$\boldsymbol{\bar{B}_{jk}} = \begin{matrix} \boldsymbol{B_{jk}/\rho A\omega} & \boldsymbol{j = 2, 3, k = 2, 3} \\ \boldsymbol{B_{jk}/\rho AB\omega} & \boldsymbol{j = 4, k = 2, 3 \text{ or } j = 2, 3, k = 4} \\ \boldsymbol{B_{jk}/\rho AB^2\omega} & \boldsymbol{j = 4, k = 4} \end{matrix}$$

   Type 3:

$$\bar{A}_{jk} = \begin{matrix} A_{jk}/\rho D^2 \\ A_{jk}/\rho D^3 \\ A_{jk}/\rho D^4 \end{matrix};\ \bar{B}_{jk} = \begin{matrix} (B_{jk}/\rho D^2)\sqrt{D/g} \\ (B_{jk}/\rho D^3)\sqrt{D/g} \\ (B_{jk}/\rho D^4)\sqrt{D/g} \end{matrix} \quad \begin{matrix} j = 2,3, k = 2,3 \\ j = 4, k = 2,3 \text{ or } j = 2,3, k = 4 \\ j = 4, k = 4 \end{matrix}$$

3.2 Required lay-out of user defined input files

User input of data-files for various purposes need to be prepared with an extension (.mat, .dat, .txt, csv etc) with a specified format as described below.

3.2.1 Ship section

A 2-column matrix (x, y) [m] defined points on ship section

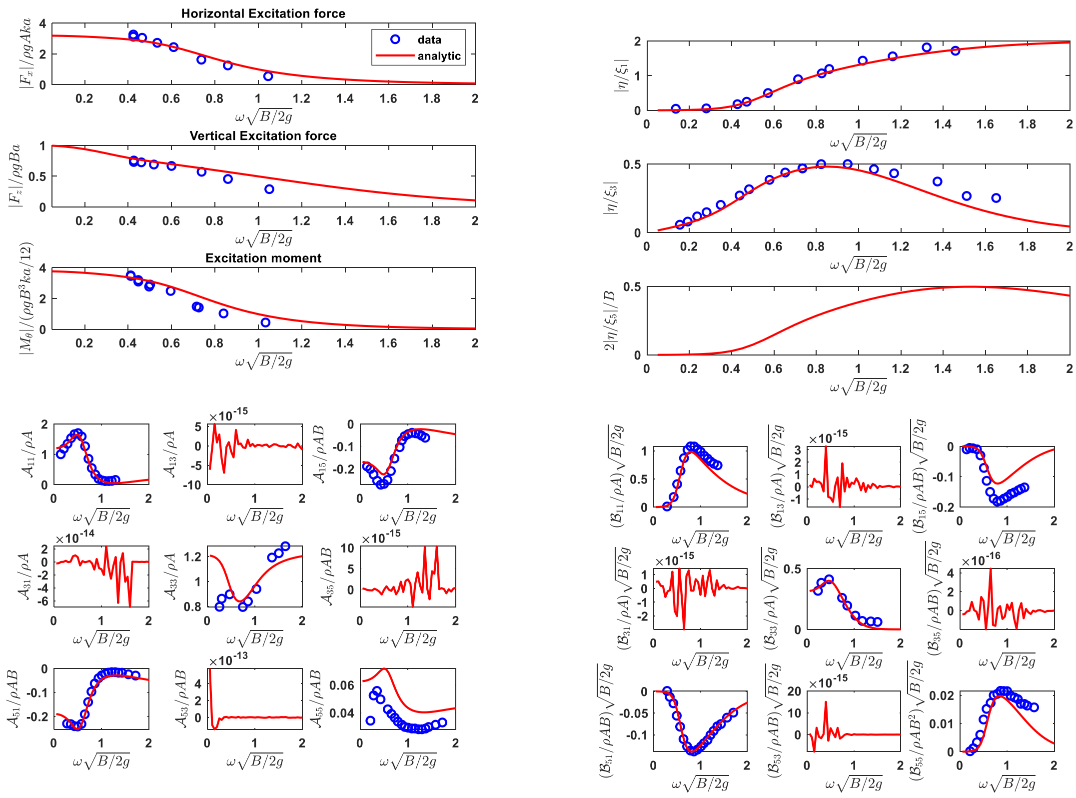
3.2.2 External measurement data

- **Diffraction calculation**: requires data set of excitation forces and/or reflection, transmission coefficients.
  First sixth columns contain data of normalized excitation forces (column 2, 4, 6 for heave, sway and roll) and the corresponding normalized wave frequency, wavelengths, etc as in the wave input panel choice (column 1, 3, 5).
  Next 4 columns are for reflection (column 8) and transmission coefficients (column 9), and the corresponding normalized wave frequency, wavelengths, etc as in the wave input panel choice (column 1, 3, 5).
- **Radiation calculation**: requires data set of added masses, damping coefficients, and radiated wave amplitude for corresponding normalized wave frequency, wavelengths, etc as in the wave input panel choice. For the simplicity description of column format in the next point, wave input data denoted by w_{jk} ,added mass A_{jk}, damping coefficients B_{jk} and radiated wave η_j,
  The columns contain data of w_{22}, A_{22} , w_{23}, A_{23}, w_{24}, A_{24}, w_{32}, A_{32} , w_{33}, A_{33}, w_{34}, A_{34}, w_{42}, A_{42} , w_{43}, A_{43}, w_{44}, A_{44}, w_{22}, B_{22} , w_{23}, B_{23}, w_{24}, B_{24}, w_{32}, B_{32} , w_{33}, B_{33}, w_{34}, B_{34}, w_{42}, B_{42} , w_{43}, B_{43}, w_{44}, B_{44}, $w_2, \eta_2, w_3, \eta_3, w_4, \eta_4$
- If some data set is not available, please add ‘0’ values, if the number of row in each data set is different, make it same by adding ‘0’ values.

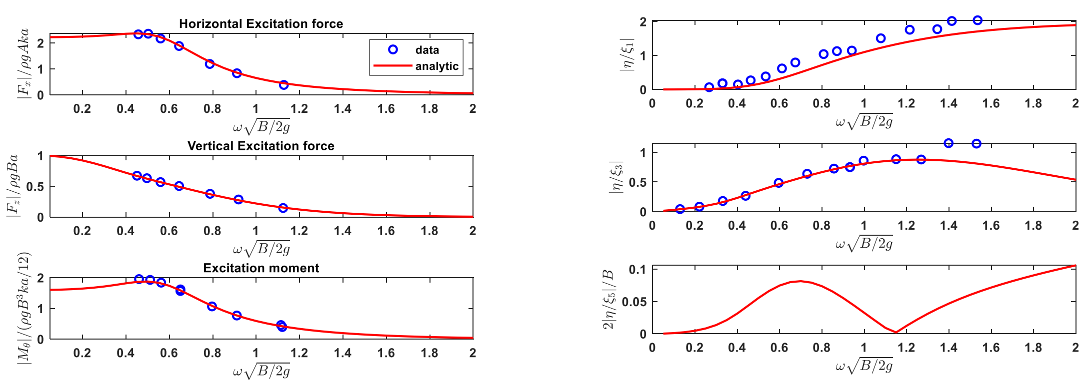
4 Test cases

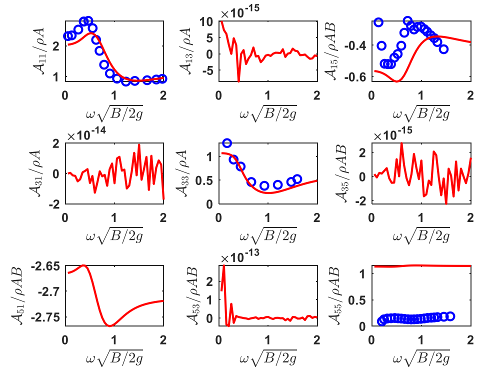
Analytic ship module provides 7 Testcases.
The basic properties of the test cases are listed with references to relevant publications in the next sections.
The project file can be found on the testcases folder: /Testcases 200928/analyticShip/.

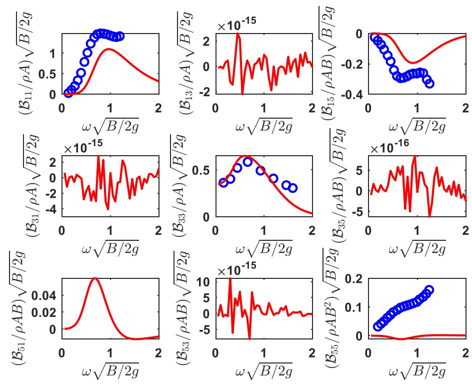
4.1 Vugts's exp barge (B=40, T=20m, D=225m)



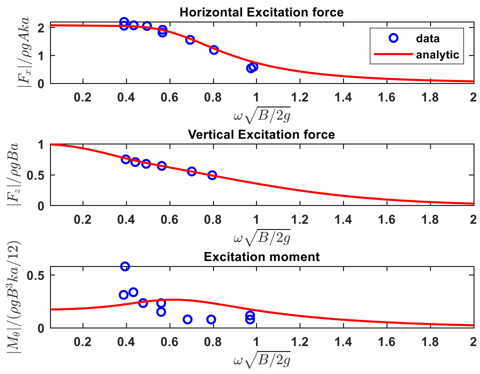
4.2 Vugts's exp wedge (B=34.6, T=30m, D=225m)

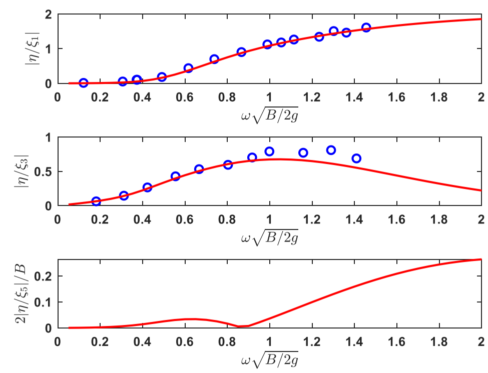


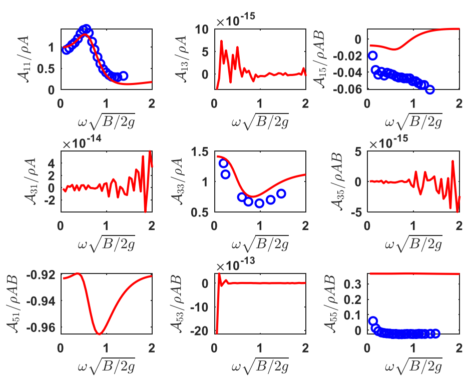


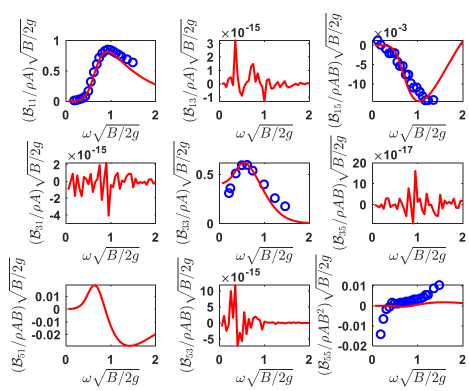


4.3 Vugts's exp halfcircle (B=40, T=20m, D=225m)

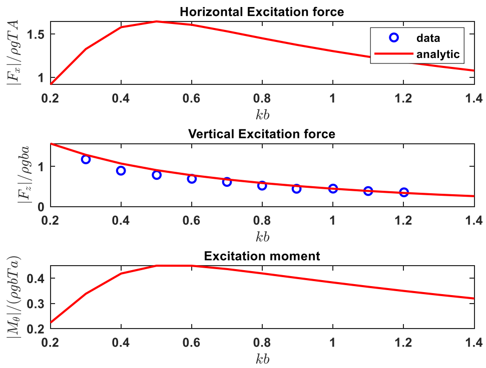


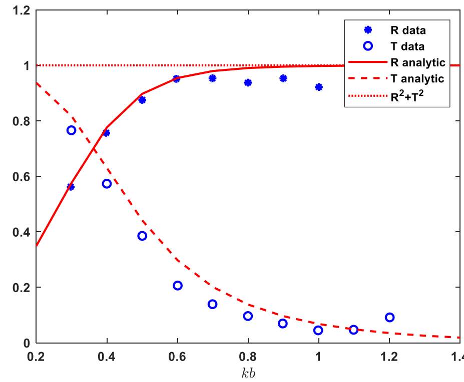






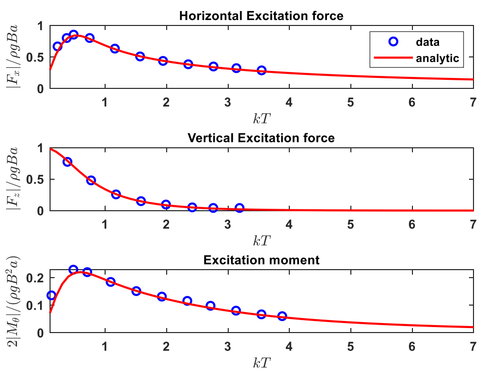
4.4 Rodriguesz (barge B=50, T=25, D=125 m)



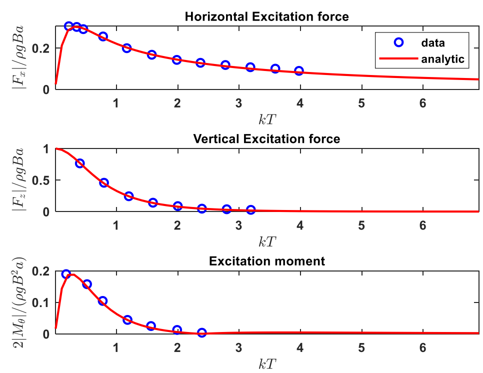


4.5 Zheng 2004

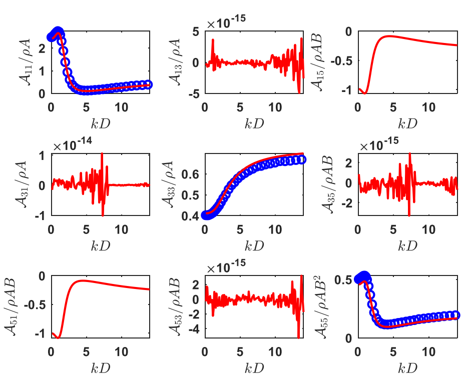
b/T=1, D/T=2, D=50

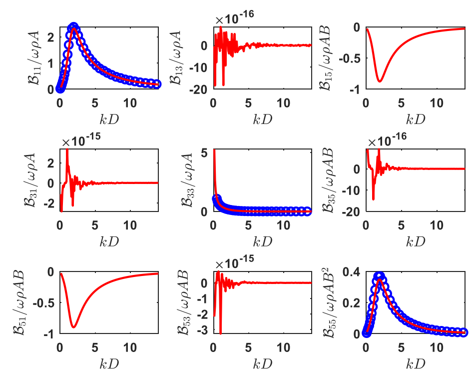


b/T=3, D/T=2, D=50



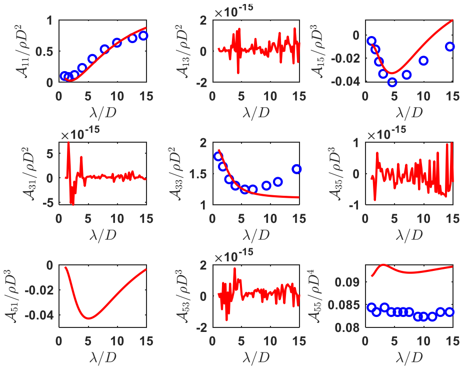
B/T=1, D/T=3, D=60

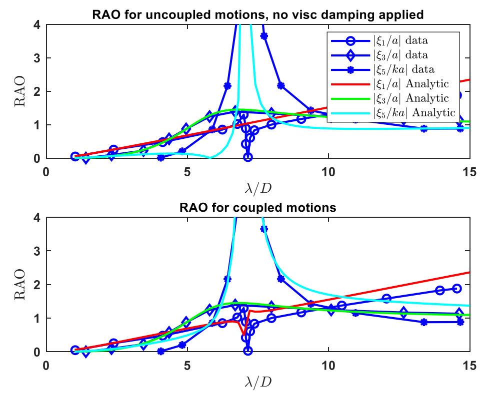


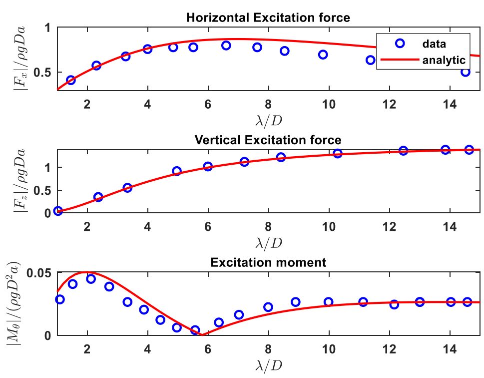


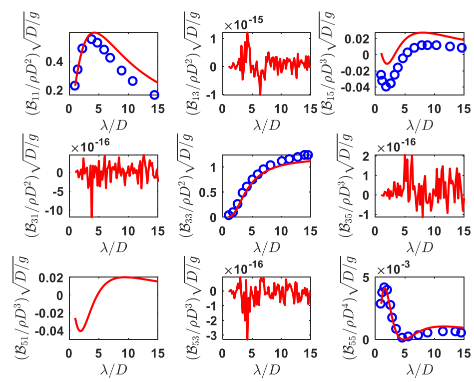
4.6 Belibassakis 2008

B=30,T=10, D=20 Slope 0

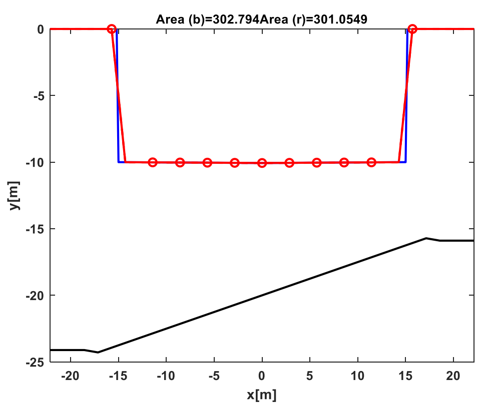


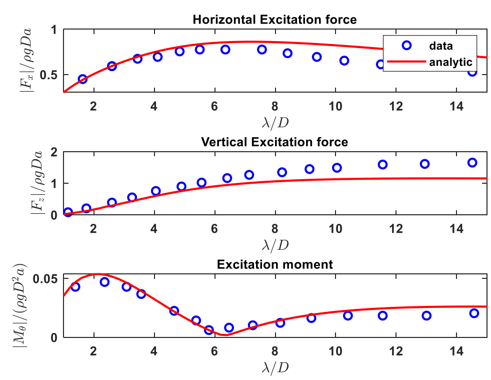


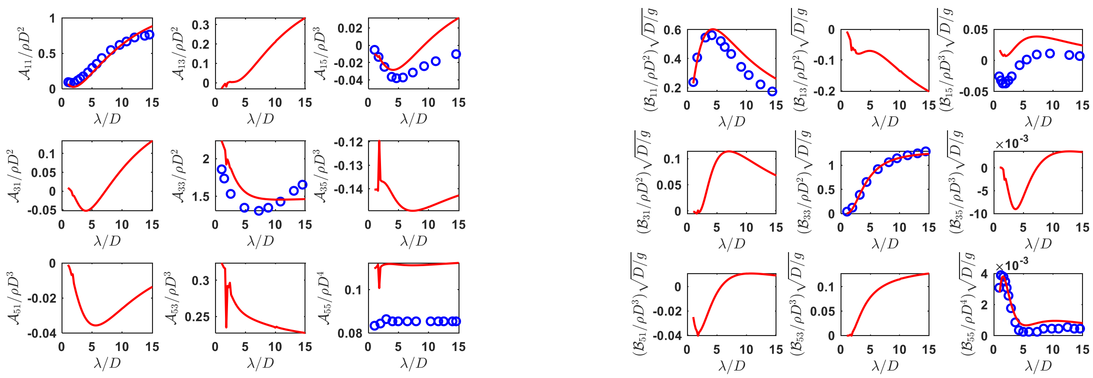




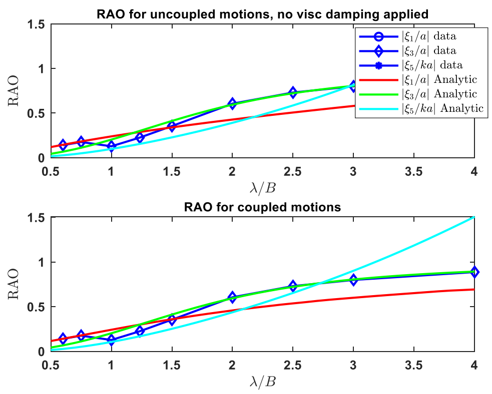
B=30,T=10, D=20 Slope 1/4







4.7 Journee (barge, B=200m, T=8m, D=231m)



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