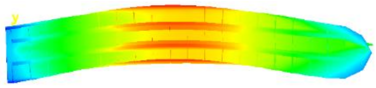
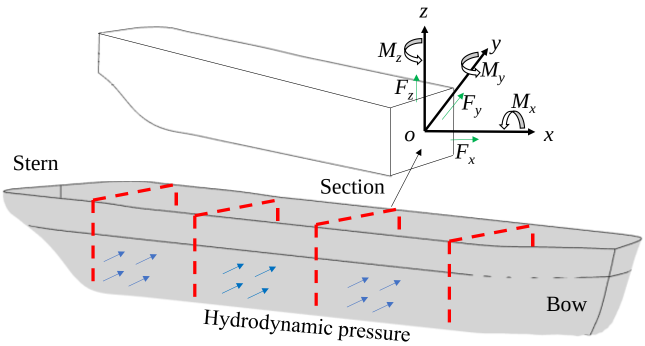
Three-dimensional Analysis Software of Wave Loads and Hydroelasticity

User Manual







OpenWALAS

(**Open** ***Wa***ve ***L***oad ***A***nalysis ***S***oftware)

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Date: ***March 3rd, 2022***

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Context

1. Software instructions

1.1. Basic information

1.1.1. Introduction

OpenWALAS (***Open Wa****ve* ***L****oad* ***A****nalysis* ***S****oftware*) is a suit of fluid-structural interaction software aiming to numerically calculate the motions, wave loads and hydroelastic responses (springing and whipping) of marine structures in waves, which is based on three-dimensional potential theory and mode superposition principle of elastic structures, as well as Morison's equation. And the velocity and pressure are respectively solved by 3D boundary element method (BEM) in frequency domain and time domain, considering forward speed, multi-body and nonlinear factors (nonlinear hydrostatic restoring force, nonlinear incident wave exciting force and slamming pressure), as well as the function of eliminating irregular frequencies of floating structures and second-order forces in frequency domain.

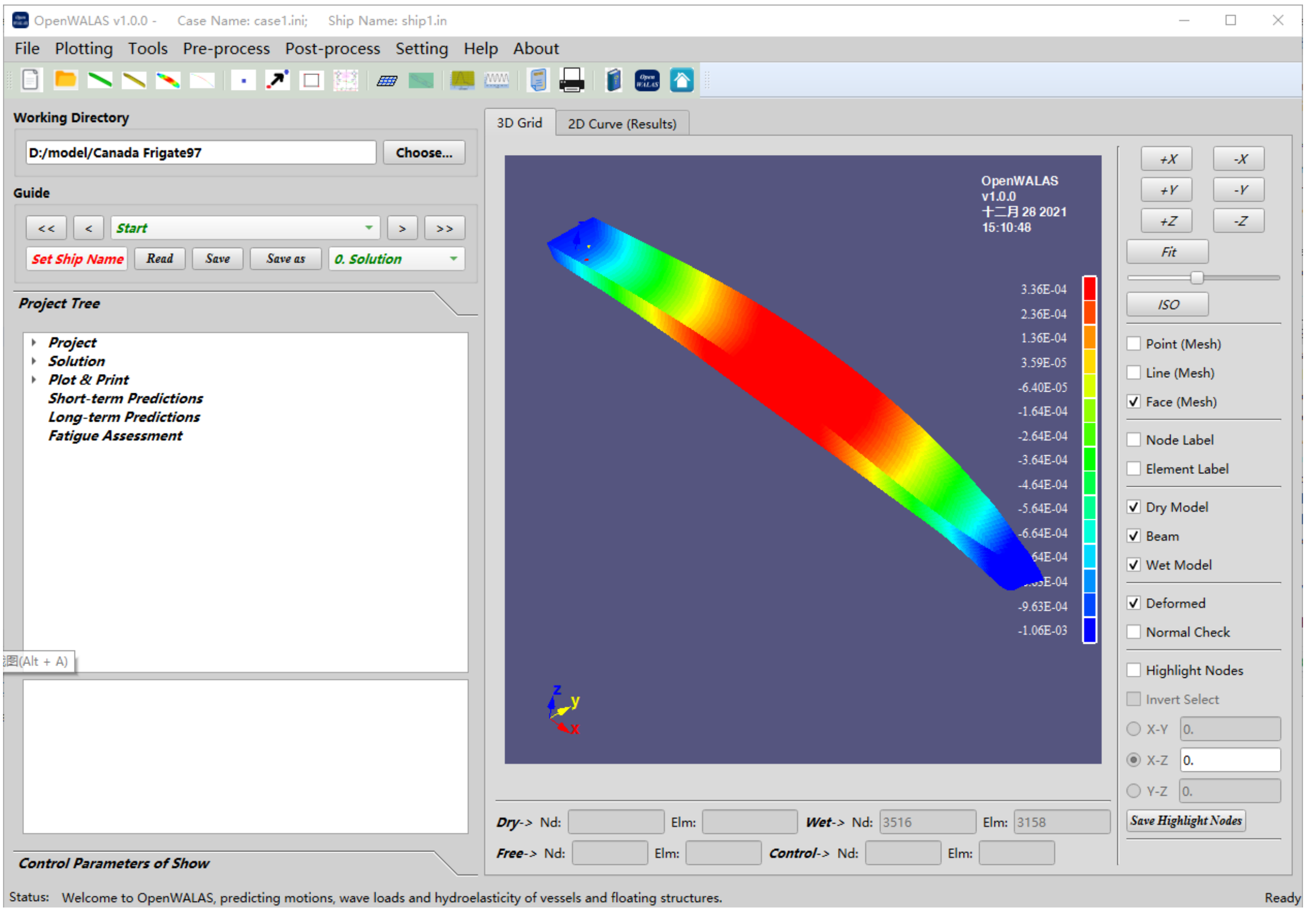


Fig. 1 OpenWALAS GUI

The project of OpenWALAS, maintained by Dr. Peng Yang on GitHub and was built originally for Yang's own research, intends to supply a suit of free (not opensource) software to scientists and engineers all over the world. Everyone can freely use the software for scientific research and academic activities, but the software must be cited in the published papers. If it is to be used for commercial purposes, it is recommended to purchase genuine software from developers.

OpenWALAS program suit contains the functions of automatic meshing of ship hulls, cut-off hull mesh, straight beam modal analysis, characteristic calculation of transverse section, as well as 3D model display and 2D curve drawing. The software suit contains the GUI program OpenWALAS and five non-GUI core programs: OpenWALAS_PRE, OpenWALAS_FSCM, OpenWALAS_TDGF, OpenWALAS _IORM and OpenWALAS _TIME_RESP. The modules of OpenWALAS_MOOR and OpenWALAS_BLADE are developing, and will be released as soon as possible. The module OpenWALAS_MOOR is to consider complex mooring systems, and the module OpenWALAS_BLADE is to assess aerodynamic performances and elastic vibrations of blades of floating offshore wind turbine.

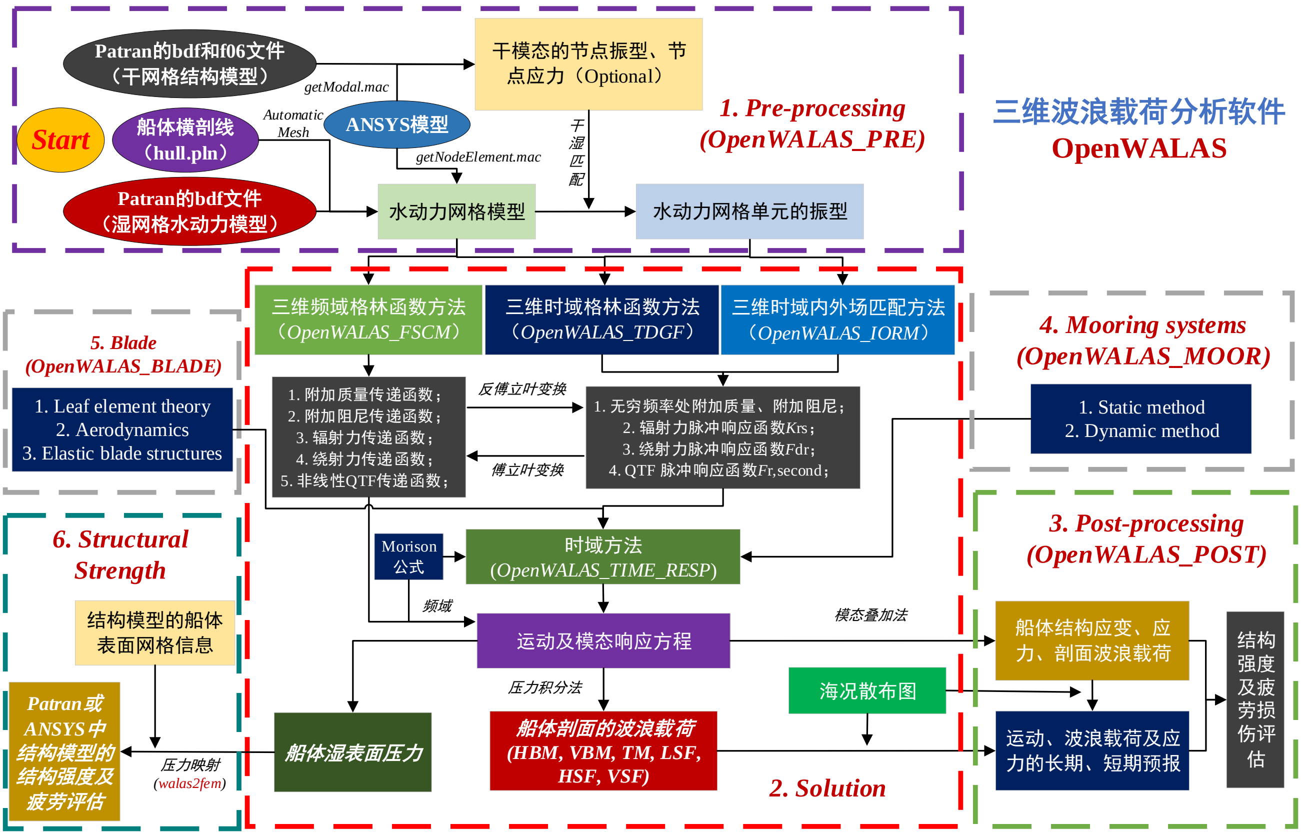


Fig. 2 Frame diagram of OpenWALAS

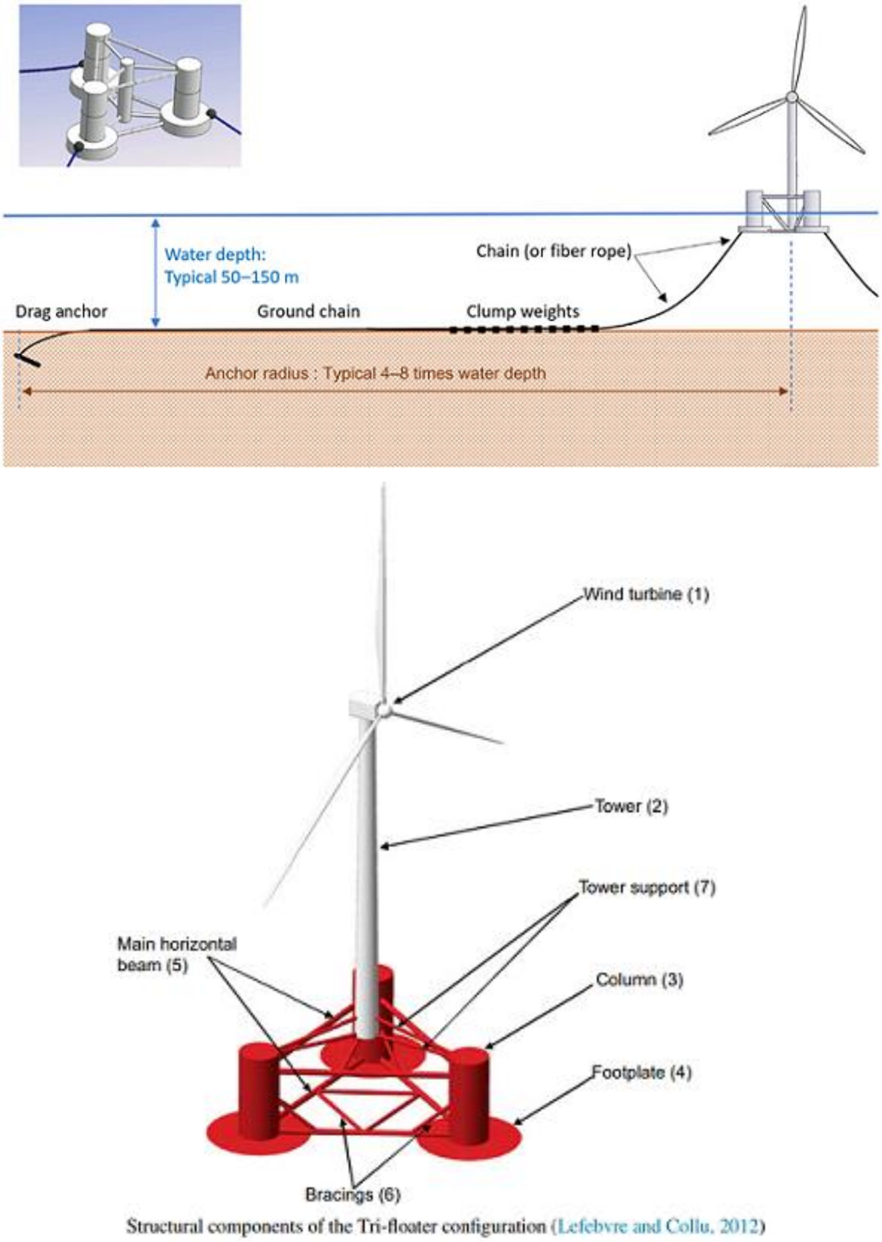


Fig. 3 Design draft of FOWT (Floating Offshore Wind Turbine) (Ma et al., 2019)

- OpenWALAS_PRE program for pre-processing, is mainly used to calculate the mode of wetted floating structures from dry modal informtions, in which the structural FEM model is 3D FEM model or beam model.
- 3D calculation and analysis function in time domain: OpenWALAS_TDGF (time domain green's function method, called 'TDGF') and OpenWALAS_IORM（Inner and outer regions matching of Rankine source, called 'IORM') are the core program. The hydrodynamic coefficients are mainly calculated, including impulse response function of radiation forces,

impulse response function of diffraction exciting forces, impulse response function of incident exciting forces, impulse response function of sectional wave loads, etc.

- 3D calculation and analysis function in frequency domain: OpenWALAS_FSCM（forward speed correction method in frequency domain, called 'FSCM') is based on the forward speed correction assumption (i.e., low speed and high frequency) boundary element method and Morison's equation in three-dimensional frequency domain, to assess the influence of forward speed. The hydrodynamic coefficients (such as incident wave exciting force, diffraction wave exciting force, added mass and added damping), motions and wave loads, hydroelastic modal responses, wetted-surface pressures, wave height distributions of surrounding fluid fields, and second-order forces are mainly calculated. It also has the function of eliminating irregular frequency by adding a rigid cover on the inner free surface using the extended integral equation. There are three methods (near-field pressure integral method, middle-field control-surface method and far-field momentum method) are proposed to calculate the second-order forces, including rigid modes and elastic modes.
- OpenWALAS_TIME_RESP is a calculating program of elastic modal responses and wave loads in time domain, which includes the functions of nonlinear incident force, hydrostatic restoring force, slamming force, Morison's equation, as well as indirect time-domain method.

1.1.2. Functions

OpenWALAS program includes the functions: automatic division of hull meshes, hull mesh splitting, modal analysis of straight beam, calculation of cross section characteristics, 3D model display and 2D curve drawing.

1.1.3. Running sequence

(a) Method I: run **OpenWALAS** *GUI* to complete input parameter setting, calculation and post-processing drawing, and complete all operations in the interface.

(b) Method II: run **OpenWALAS** *non-GUI* to complete input parameter setting, calculation.

(i) Three-dimensional frequency-domain calculating module: *OpenWALAS_PRE* → *OpenWALAS_FSCM*.

(ii) Three-dimensional indirect time-domain calculating module: *OpenWALAS_PRE* →

OpenWALAS_FSCM → *OpenWALAS_TIME_RESP*.

(iii) Three-dimensional direct time-domain calculating module: *OpenWALAS_PRE* → *OpenWALAS_TDGF* or *OpenWALAS_IORM* → *OpenWALAS_TIME_RESP*.

1.1.4. Ways of input parameters

There are two ways to input parameters in this program.

(a) First way (GUI), as shown in Chapter 3.

(b) Second way (non-GUI), as shown in Chapter 4.

1.2. Compiling and development environments

Programing language: C/C++.

Compiling environments: Qt + Eclipse + MinGW(GCC) + gsl. Qt (C++) is the development library of the GUI of OpenWALAS. Eclipse is integrated development environment. MinGW (GCC) is the compiler of C language. Gsl is the numerical libraries in C language.

Development environment versions: 1. Qt - 5.14.0; 2. MinGW (GCC) – 8.1.0; 3. Gsl - 2.7; 4. Qwt - 6.2.0; 5. Opencv - 4.5.3.

1.3. Installation and running environments

The software is suitable for Windows XP, Win 7, Win 8, Win 10 and other mainstream window operating systems with 32-bit or 64-bit versions. Moreover, the software suite is suitable for Linux, UNIX and Mac OS operating systems with 32-bit and 64-bit versions.

MSC.Patran/Nastran 2005 or higher version (only required for structural elastic modal analysis).

2. Theoretical fundamental

2.1. Coordinate systems

The dry structure coordinates and wet coordinates are: the positive direction of x axis points to the bow, y axis points to the port side, z axis points up, which obey right-hand rule.

The dry structure coordinate system can be different from the wet coordinate system, defined in files of floating structures (ship.in).

In the internal calculation and output results of the program, all the coordinate origins are converted to the wet coordinate origin at the projection of the still water surface (i.e. the reference coordinate system is used in the internal calculation).

The ships are straightly travelling with constant forward speed U_0. For convenience of presentation, three coordinate systems are established shown in Fig. 4, which are

(1) The space fixed coordinate system $O_0x_0y_0z_0$: the coordinate origin is located at the still water surface, the axis O_0x_0 points to the bow, the axis O_0y_0 points to the port side, and the axis O_0z_0 is upward perpendicular to the still water surface.

(2) The equilibrium coordinate system (also called reference coordinate system) $Oxyz$: the coordinate system moves forward accompanying ship along x axis at constant speed U_0, which coincides with the space fixed coordinate system $O_0x_0y_0z_0$ at the initial moment. And, the axis Ox keeps toward the axis O_0x_0 during ship motion.

(3) The local coordinate system $O'x'y'z'$: this coordinate system is fixed on the hull. When the hull is in the equilibrium position, this coordinate system overlaps with the equilibrium coordinate system. The origin position changes with the translational motion of the hull and the direction changes with the rotation of the hull.

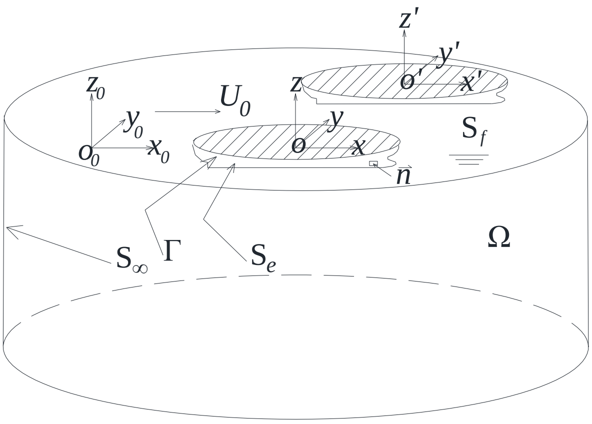


Fig. 4 Sketch of the coordinate systems

The fluid boundary is combined by wetted body surface S_e, free surface S_f, intersection of body surface and free surface Γ, infinite boundary S_∞. Ω denotes the fluid field. $\vec{n}$ denotes the normal direction of body surface towards the inner of ship hull. U_0 denotes forward speed of ship hull.

Both of the space fixed coordinate system and the equilibrium coordinate system obey right-hand rule. There are the following coordinate transformation relations.

$$\begin{cases} x_0 = x + U_0 t, y_0 = y, z_0 = z, \nabla_{x_0} = \nabla_x \\ \left.\dfrac{\partial}{\partial t}\right|_{x_0} \to \left.\dfrac{\partial}{\partial t}\right|_x - U_0 \left.\dfrac{\partial}{\partial x}\right|_x \end{cases} \tag{1}$$

2.2. Wave direction and expression

The definition of wave direction β shown in Fig. 5, 0 degree and 180 degree denote following sea and heading sea, respectively.

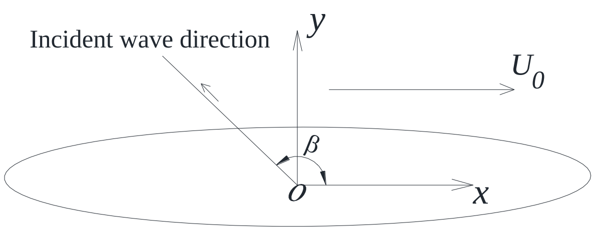


Fig. 5 Sketch of wave direction

The first-order formula of the instantaneous height of the incident wave is

$$\zeta = Ae^{\mathrm{i}k(x\cos\beta + y\sin\beta) - \mathrm{i}\omega t} \tag{2}$$

where the variables A, k and ω denote the wave amplitude, wave number and natural wave frequency, respectively. In addition, $\nu=\omega^2/g$ and $k\tanh kh=\nu$.

The first order formula of incident velocity potential $\Phi_{\rm I}$ in the equilibrium coordinate system is

$$\Phi_{\rm I}=\mathrm{Re}\left[\phi_{\rm I}\mathrm{e}^{-\mathrm{i}\omega t}\right]=\mathrm{Re}\left[\frac{Ag}{\mathrm{i}\omega}\frac{\cosh k(z+h)}{\cosh kh}\mathrm{e}^{\mathrm{i}k(x\cos\beta+y\sin\beta)-\mathrm{i}\omega t}\right] \tag{3}$$

where $\phi_{\rm I}$, h and g denote the amplitude of the incoming potential of fluid, the water depth and the gravitational acceleration constant, respectively.

2.3. Multi floating structures

The software calculates the hydrodynamic interactions of different floating structures, including the coupled diffraction potential, radiation potential, motions and wave loads.

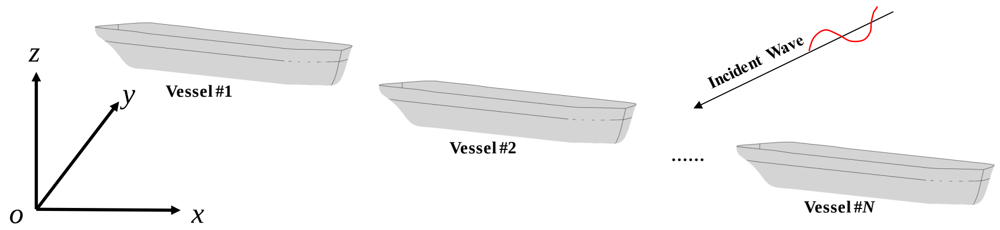
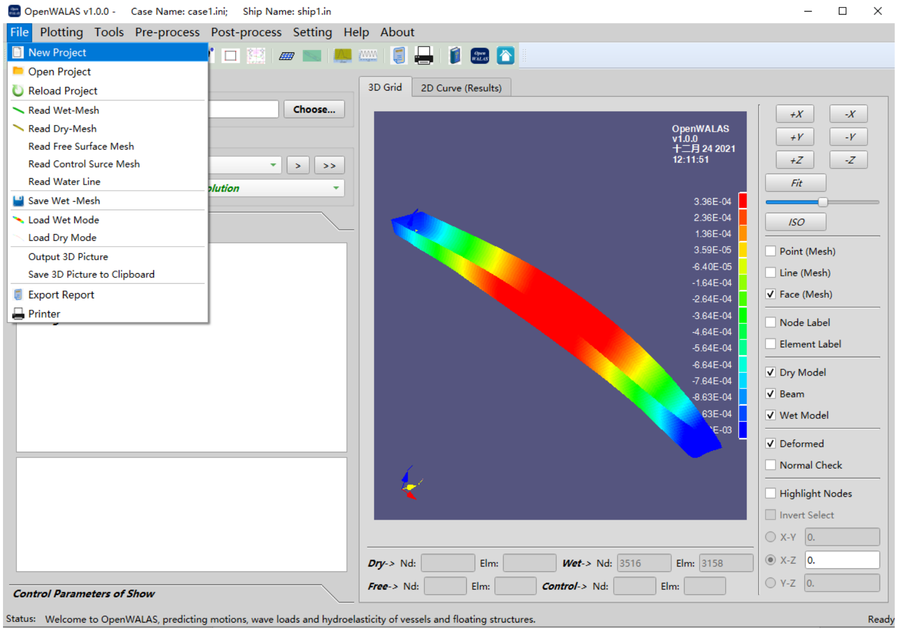


Fig. 6 Sketch of multi floating structures

3. Introduction of OpenWALAS GUI

3.1. Main GUI

3.1.1. New Project (case.in)



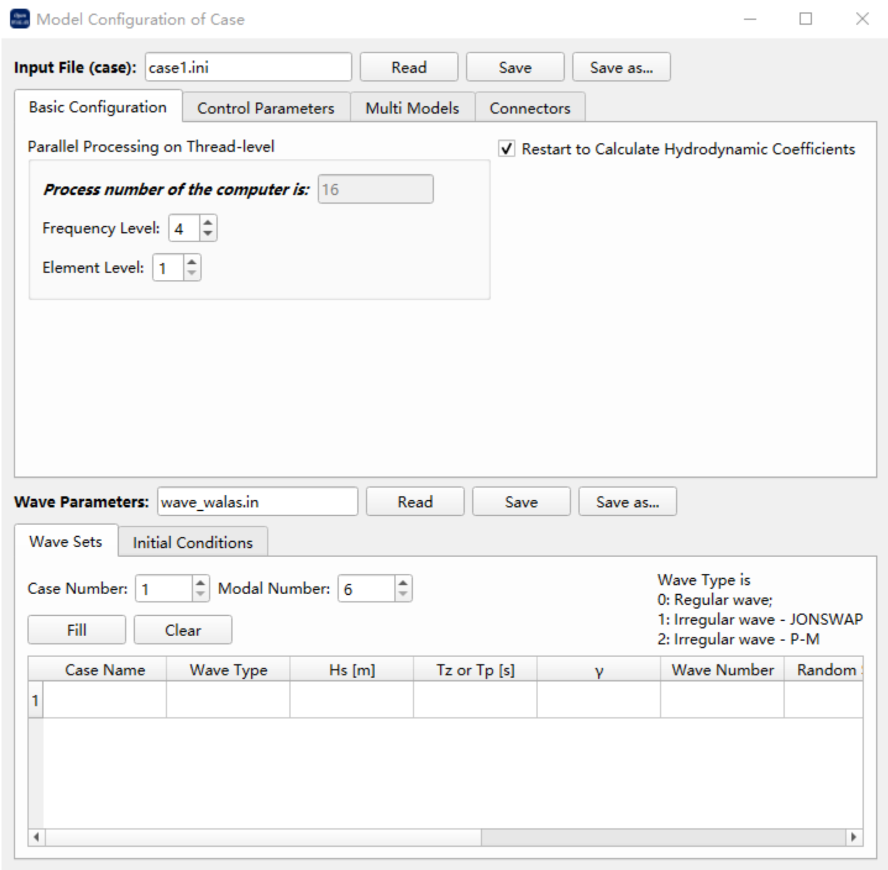
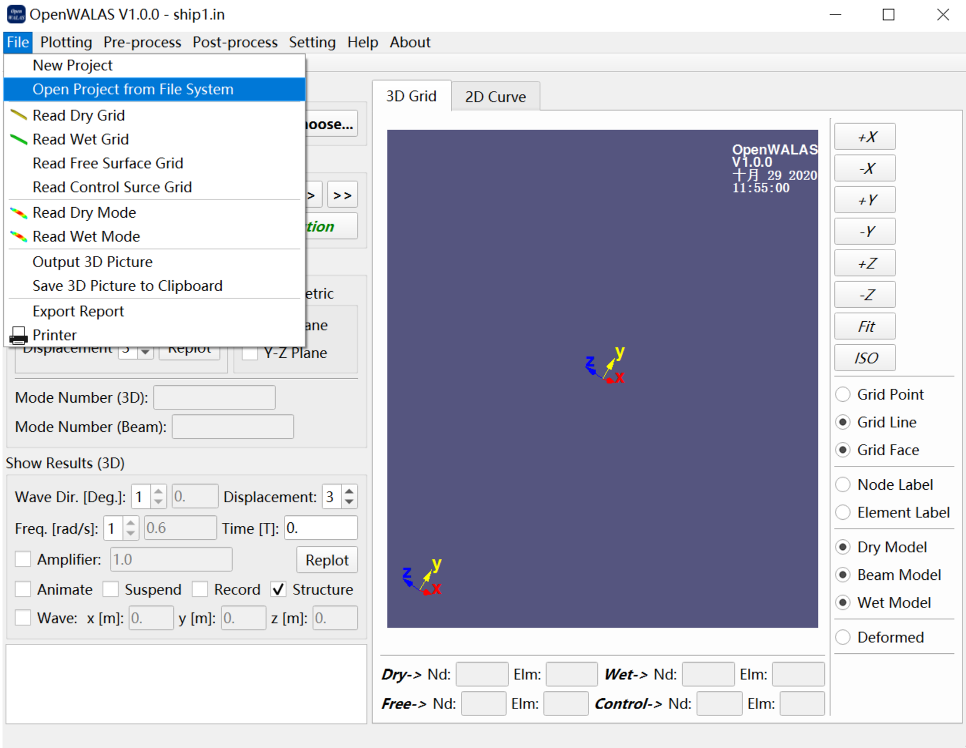


Fig. 7 New configuration file of new project

3.1.2. Open Project (case.ini)



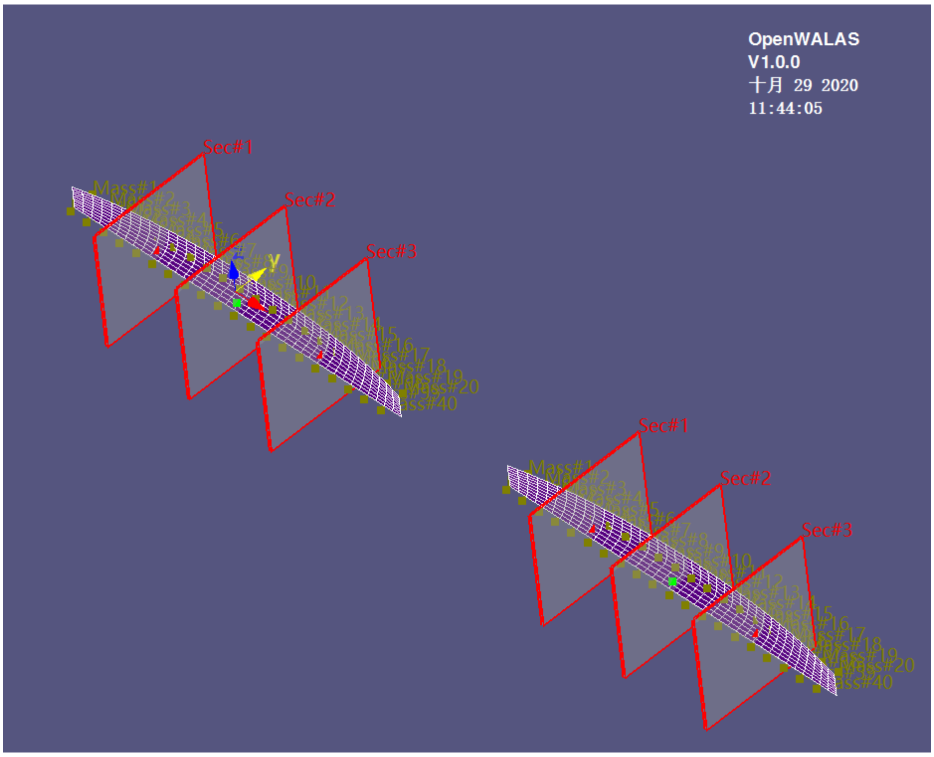


Fig. 8 Multi floating structures

3.1.3. Set working directory

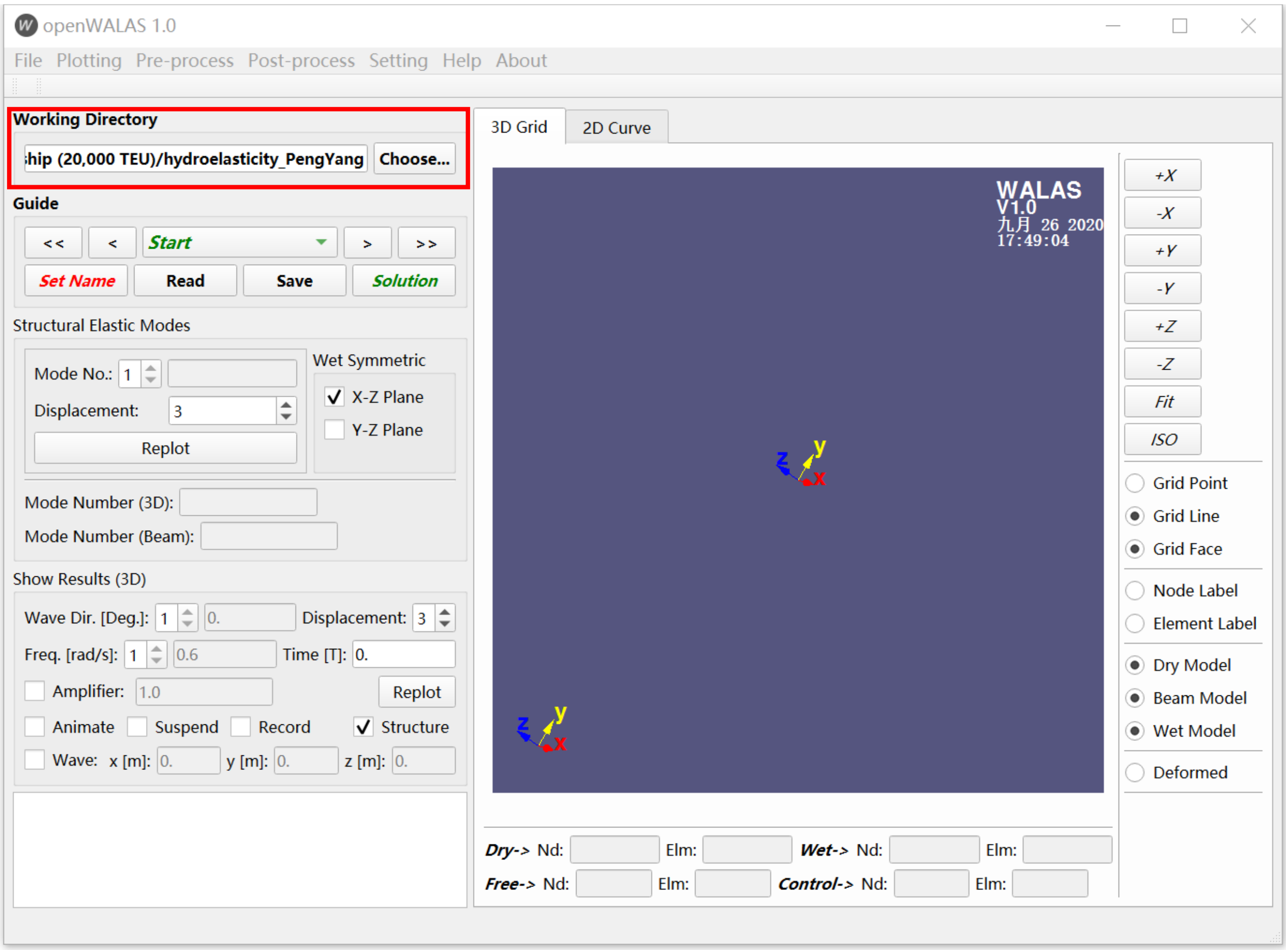


Fig. 9 Working directory

3.1.4. Set a file name of floating structure

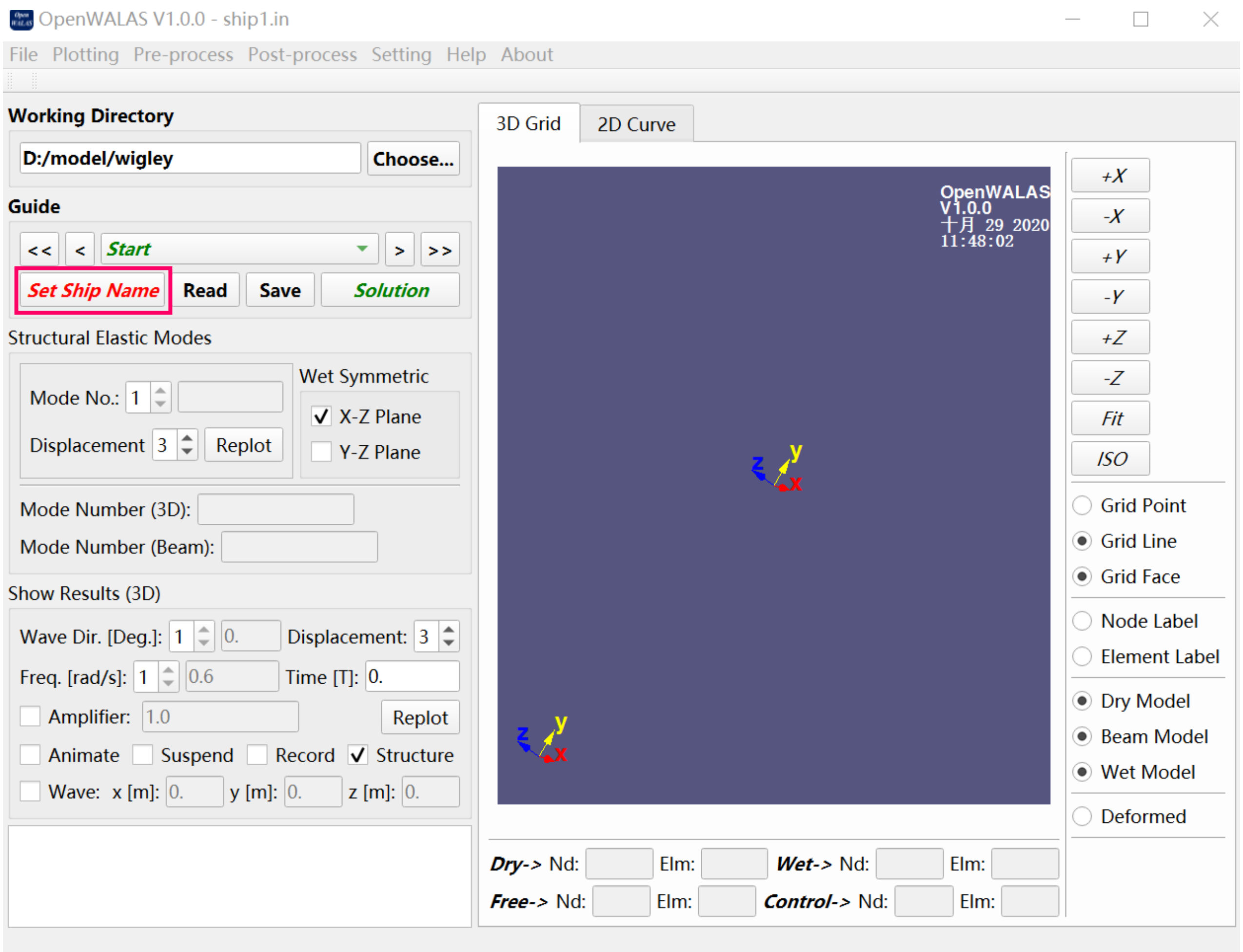


Fig. 10 Set file name

3.1.5. Read model of single floating structure (shipX.in)

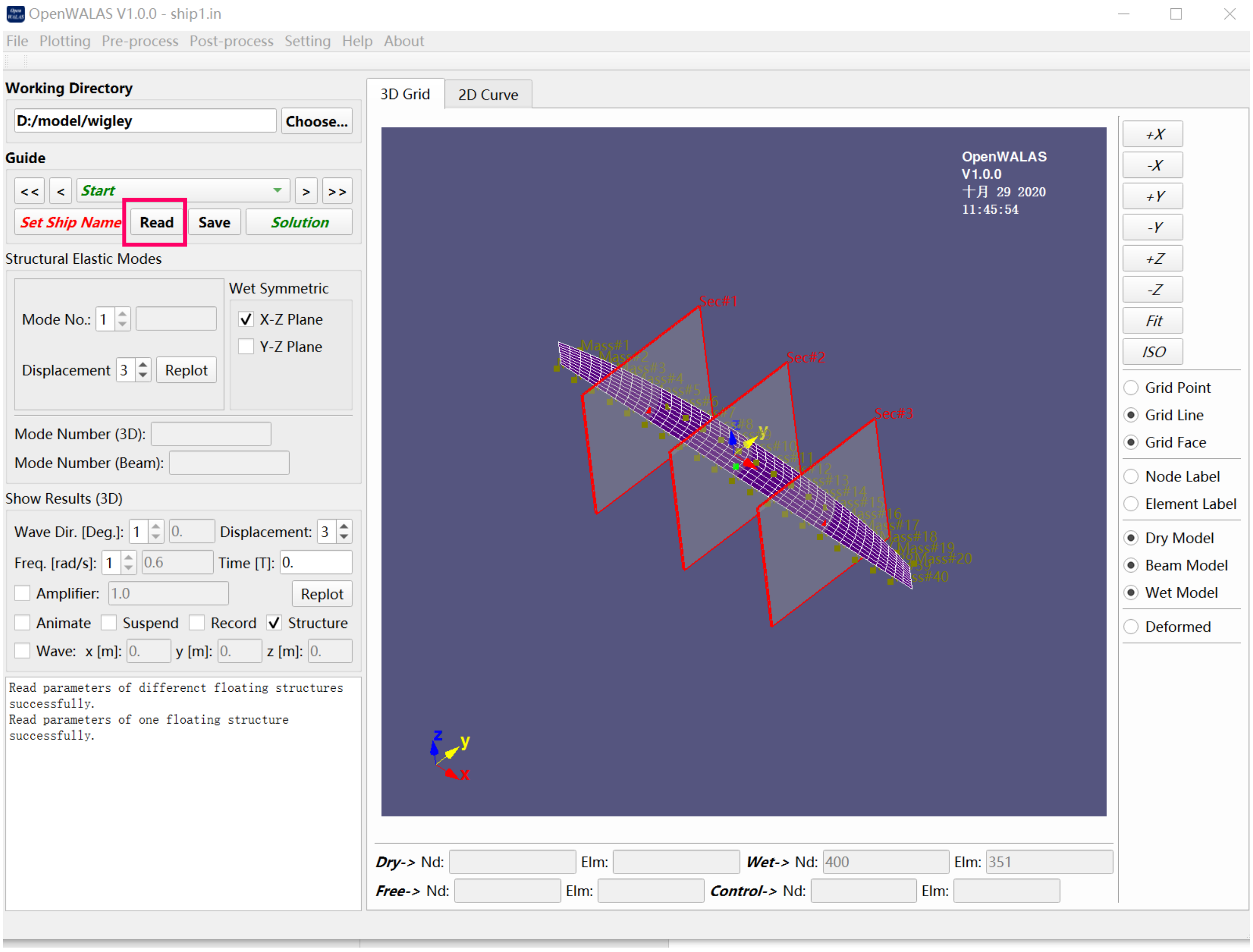


Fig. 11 One floating structure

3.1.6. Show dry model

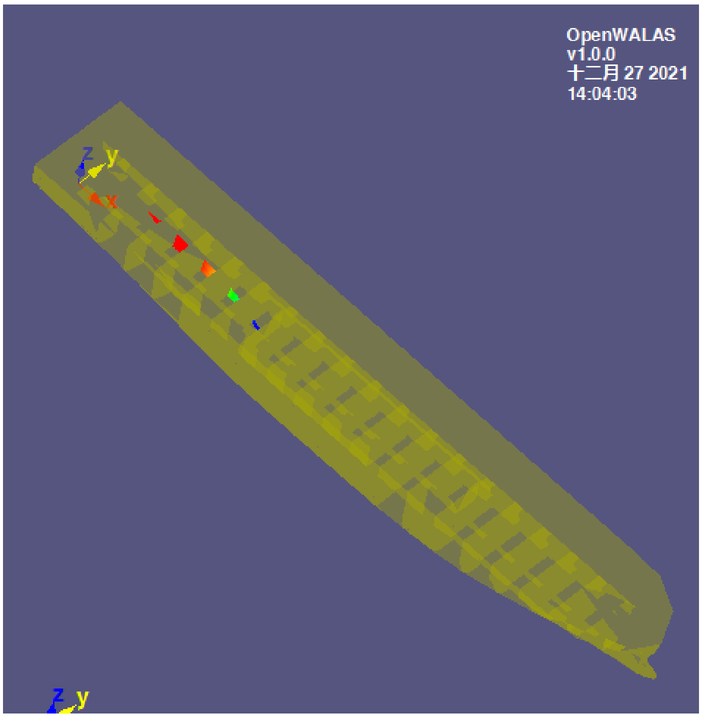


Fig. 12 3D FEM model

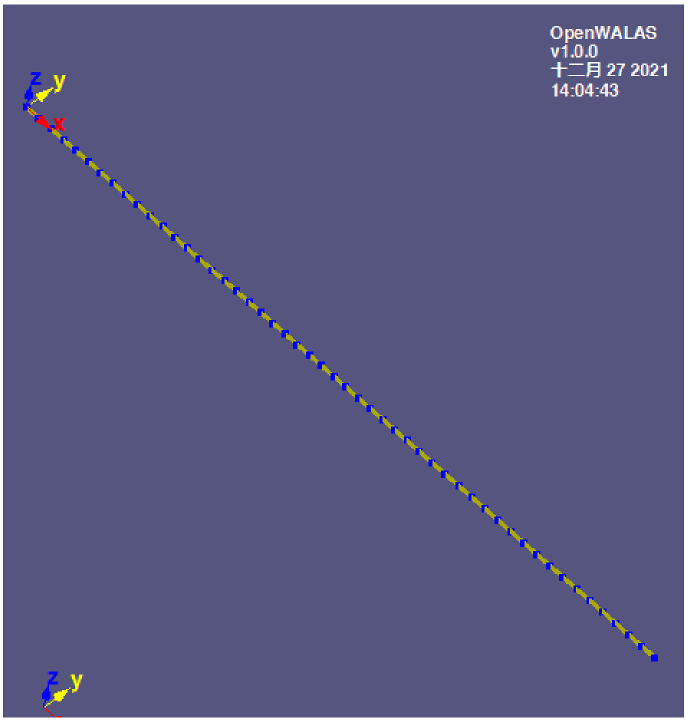


Fig. 13 1D beam model

3.1.7. Show wet model

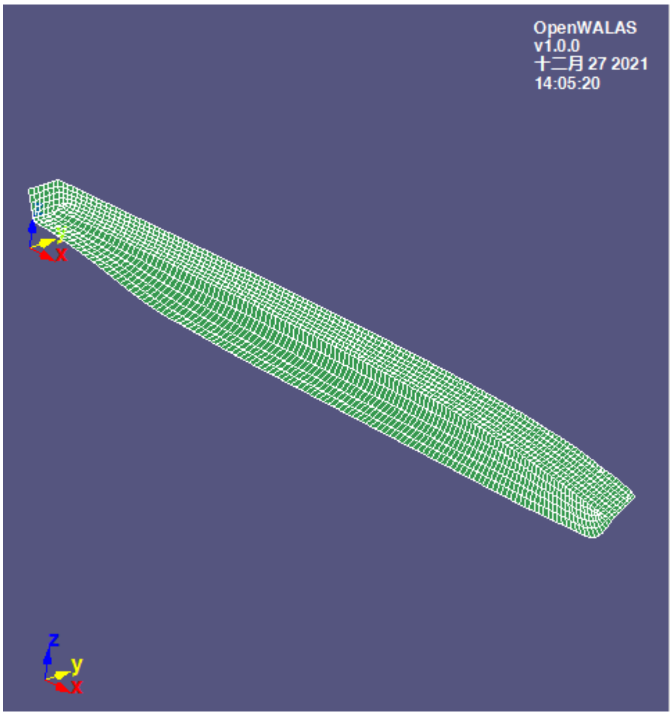


Fig. 14 3D wet model

3.1.8. Show free surface model

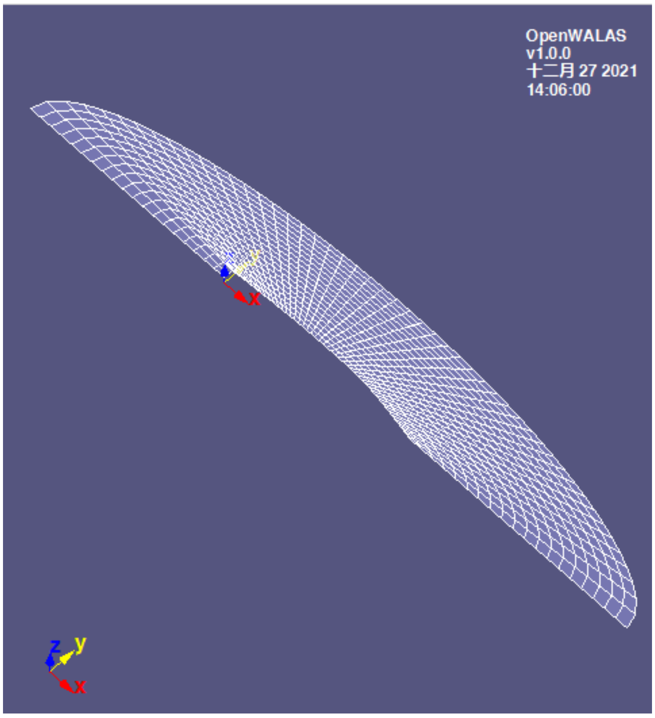


Fig. 15 Meshes on free surface

3.1.9. Show control surface model

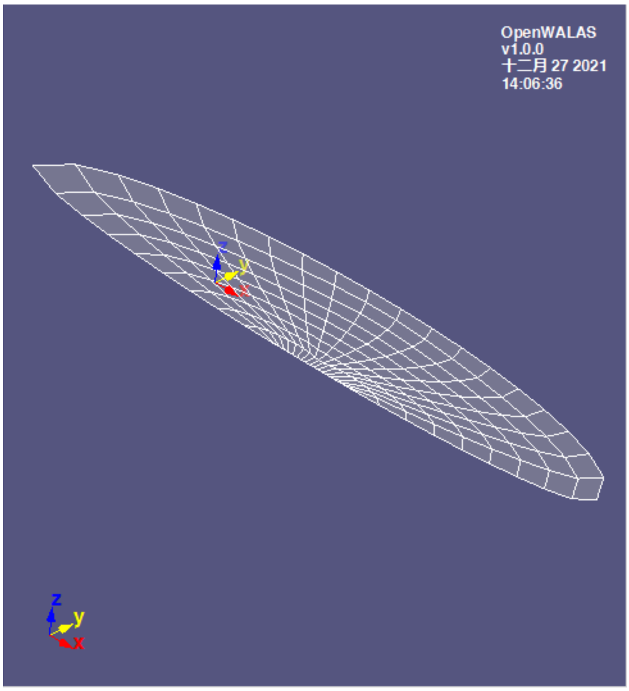


Fig. 16 Meshes on control surface

3.1.10. Show modes of dry models

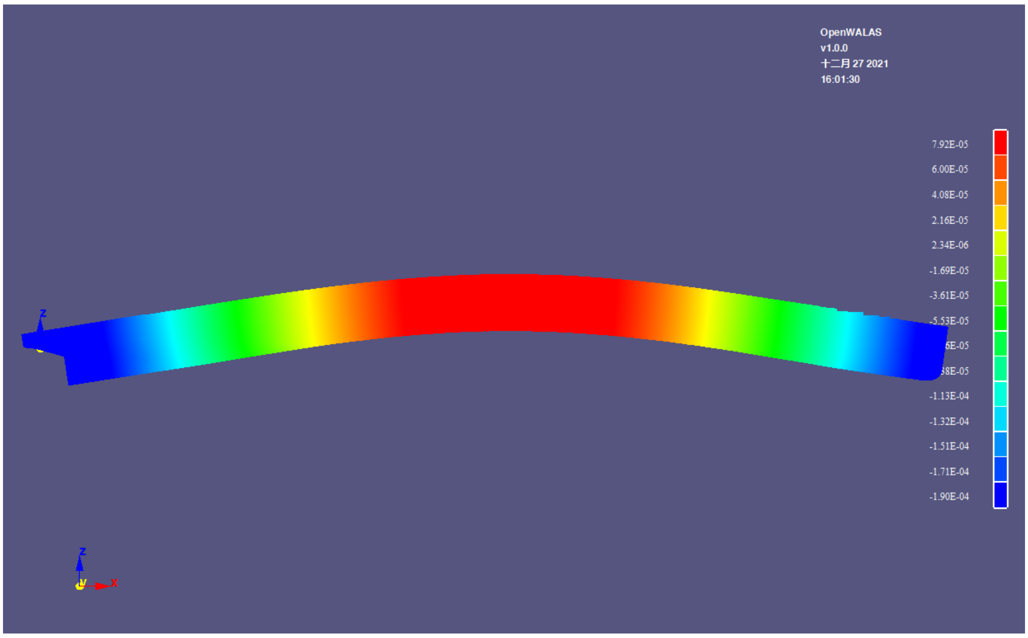


Fig. 17 3D FEM model

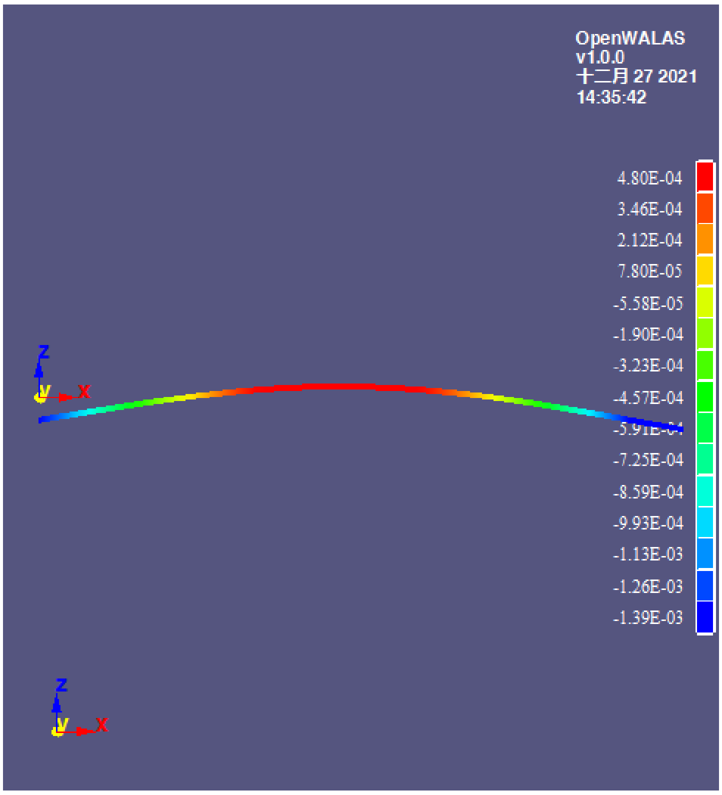


Fig. 18 1D beam model

3.1.11. Show modes of wet models

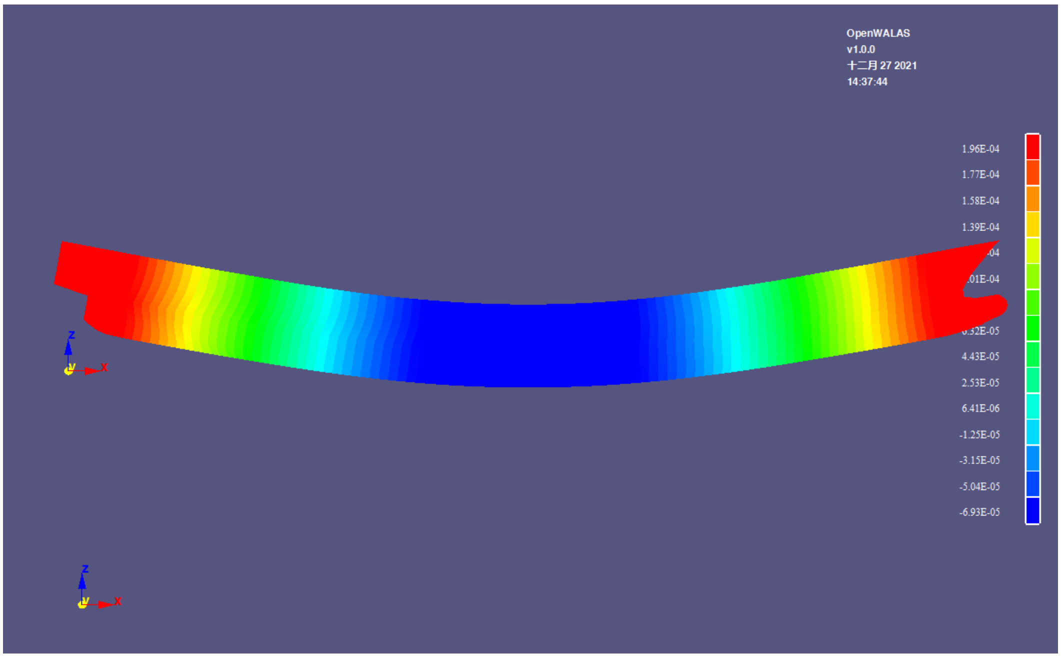


Fig. 19 3D wet model

3.2. Pre-process

3.2.1. Grid meshing

(1) Automatic meshing on ship hull

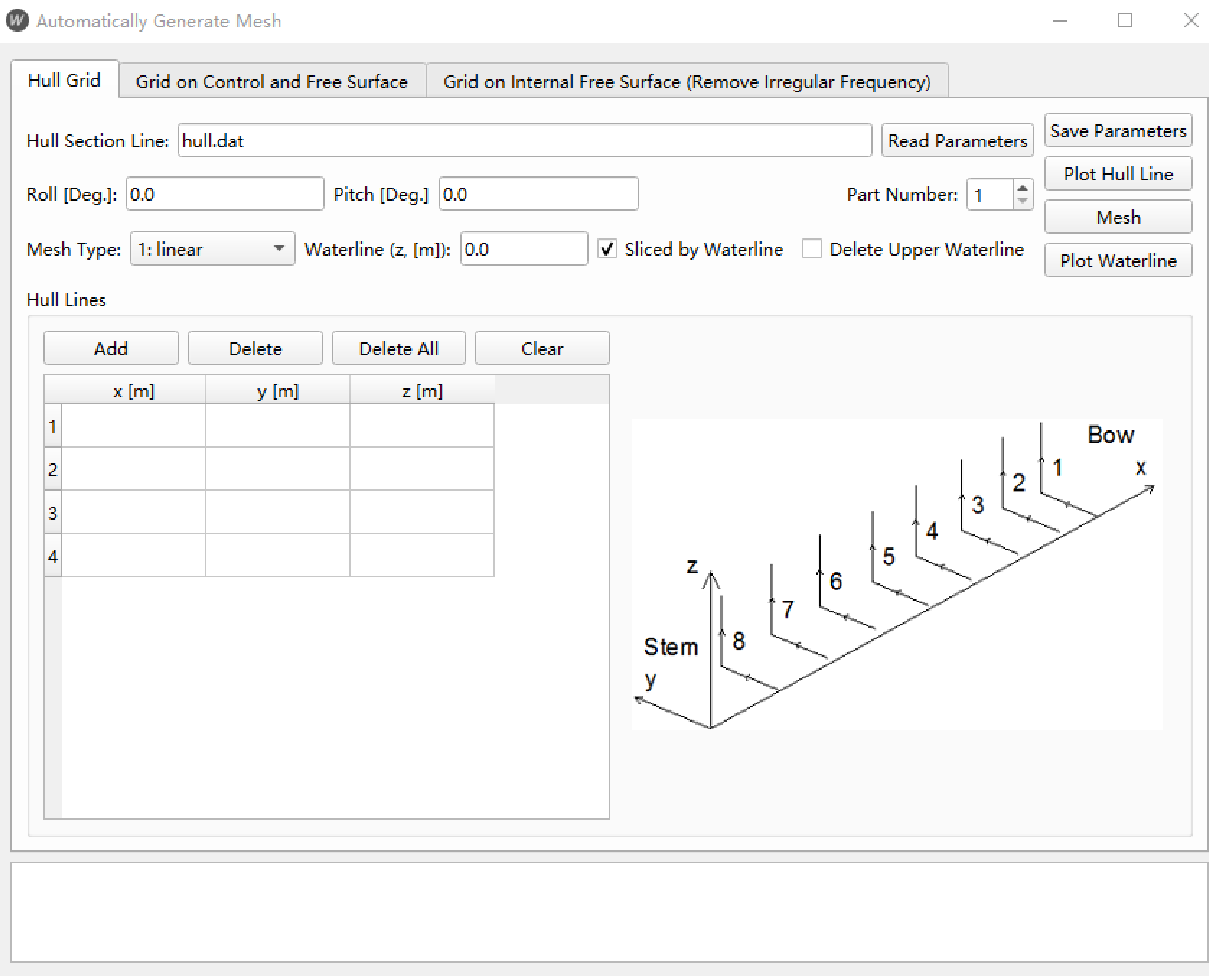


Fig. 20 Meshing on ship hulls

The format of file “hull.dat”:

roll pitch reverseNorm

partNum, spline_type, zWL, slice_flag, delFlag

xn1   yn1

lineNum

pointNum

p1x p1y p1z

…

pnx pny pnz

s

Explanation:

roll pitch reverseNorm: roll and pitch about gravity center; whether to reverse the normal direction, 0 – No, 1 – Yes.

partNum: the number of parts of the grid model

spline_type：type of grid

1: linear   2: polynomial   3: cspline 4: cspline_periodic

5: akima   6: akima_periodic   7: steffen

*zWL:*the height of water line

slice_flag: whether or not split grid by still water surface, 0 - No, 1- Yes

delFlag: whether or not delete the grid above still water surface, 0 - No, 1- Yes

Example：

```
0           0           0
3           1           0           1           0
40 18
2
6
1.500E+01   0.000E+00   -1.875E+00
1.500E+01   0.000E+00   -1.500E+00
1.500E+01   0.000E+00   -1.125E+00
1.500E+01   0.000E+00   -7.500E-01
1.500E+01   0.000E+00   -3.750E-01
1.500E+01   0.000E+00   0.000E+00
6
1.350E+01   0.000E+00   -1.875E+00
1.350E+01   1.203E-01   -1.500E+00
1.350E+01   2.126E-01   -1.125E+00
1.350E+01   2.785E-01   -7.500E-01
1.350E+01   3.180E-01   -3.750E-01
1.350E+01   3.312E-01   0.000E+00
10 10
3
6
1.200E+01   0.000E+00   -1.875E+00
1.200E+01   2.327E-01   -1.500E+00
1.200E+01   3.988E-01   -1.125E+00
1.200E+01   5.157E-01   -7.500E-01
1.200E+01   5.858E-01   -3.750E-01
```

1.200E+01 6.091E-01 0.000E+00
6
1.050E+01 0.000E+00 -1.875E+00
1.050E+01 3.564E-01 -1.500E+00
1.050E+01 5.735E-01 -1.125E+00
1.050E+01 7.218E-01 -7.500E-01
1.050E+01 8.104E-01 -3.750E-01
1.050E+01 8.400E-01 0.000E+00
6
9.000E+00 0.000E+00 -1.875E+00
9.000E+00 5.045E-01 -1.500E+00
9.000E+00 7.477E-01 -1.125E+00
9.000E+00 9.047E-01 -7.500E-01
9.000E+00 9.980E-01 -3.750E-01
9.000E+00 1.029E+00 0.000E+00
10 10
2
6
7.500E+00 0.000E+00 -1.875E+00
7.500E+00 6.780E-01 -1.500E+00
7.500E+00 9.240E-01 -1.125E+00
7.500E+00 1.068E+00 -7.500E-01
7.500E+00 1.153E+00 -3.750E-01
7.500E+00 1.181E+00 0.000E+00
6
6.000E+00 0.000E+00 -1.875E+00
6.000E+00 8.659E-01 -1.500E+00
6.000E+00 1.097E+00 -1.125E+00
6.000E+00 1.212E+00 -7.500E-01
6.000E+00 1.278E+00 -3.750E-01
6.000E+00 1.300E+00 0.000E+00

(2) Meshing on free surface and control surface

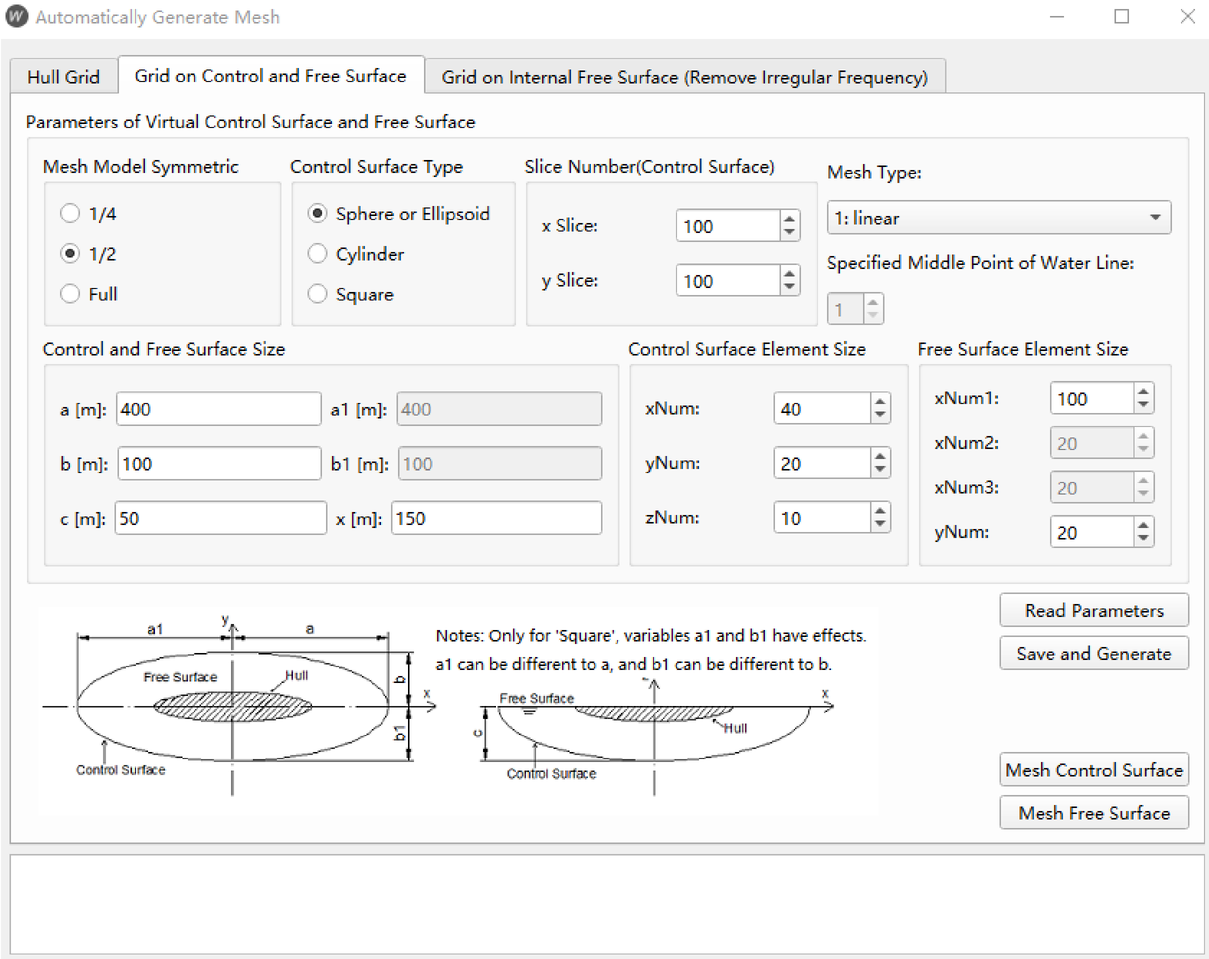


Fig. 21 Meshing on free surface and control surface

(3) Meshing on internal free surface

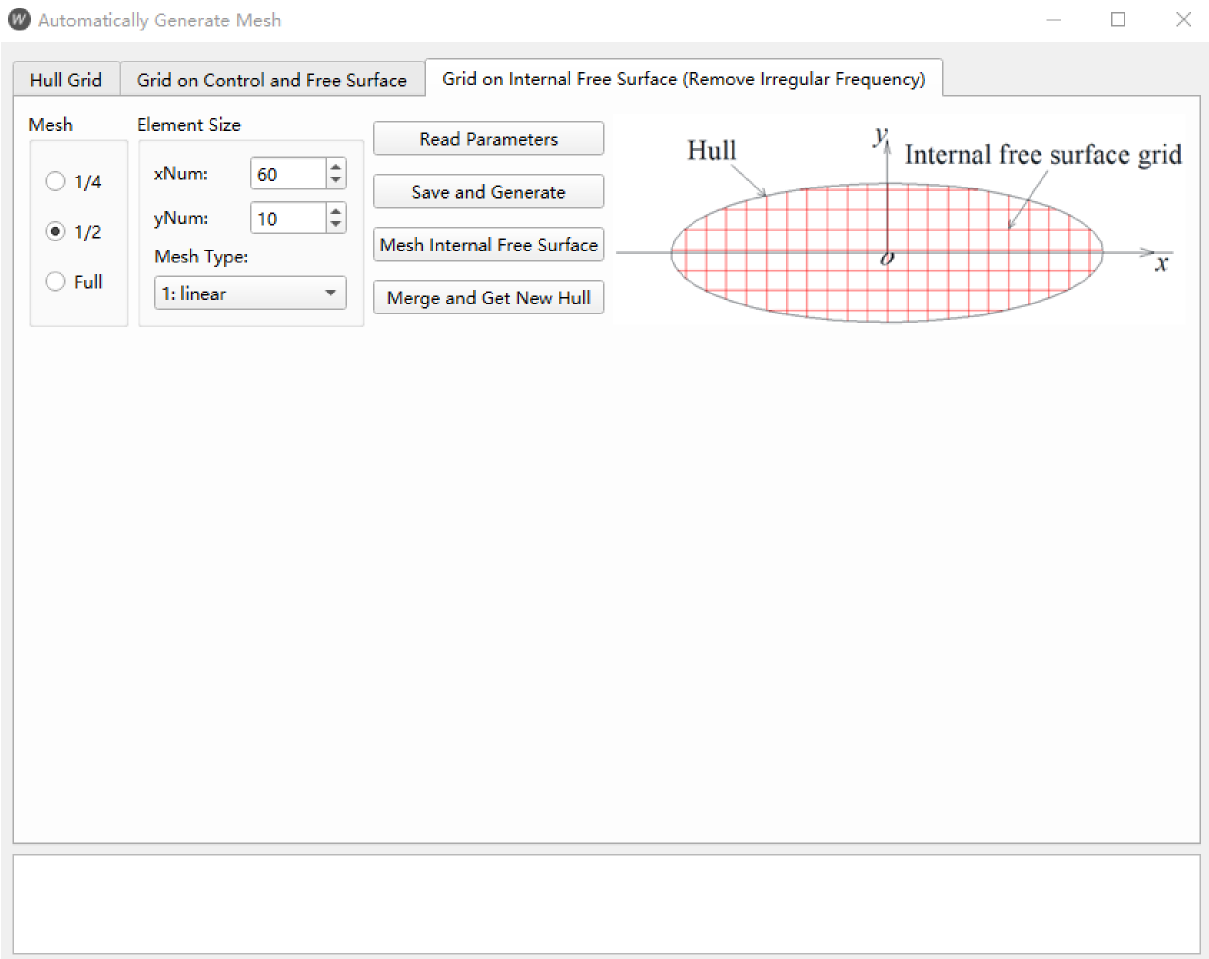


Fig. 22 Meshing on internal free surface

3.2.2. Splitting grid

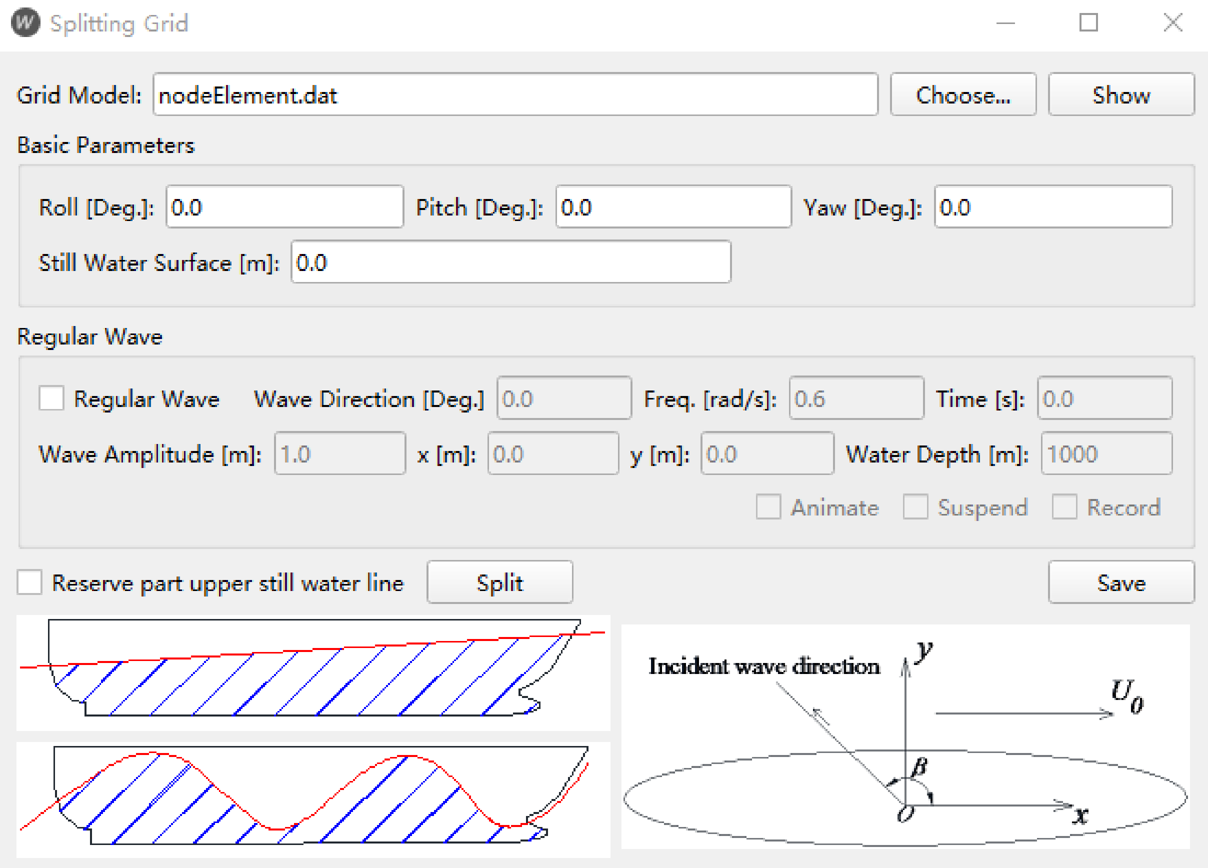
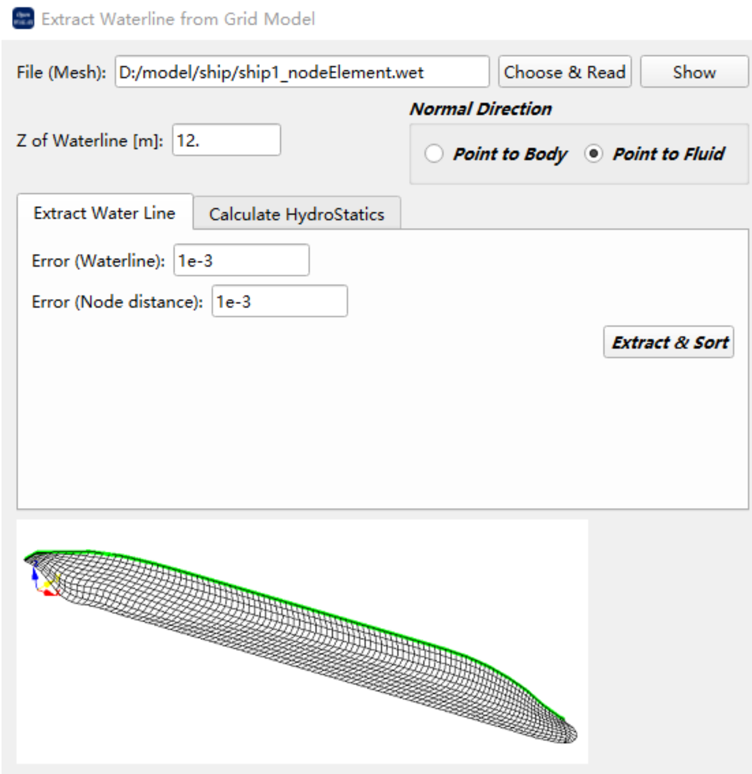


Fig. 23 Splitting grid

3.2.3. Extract water line



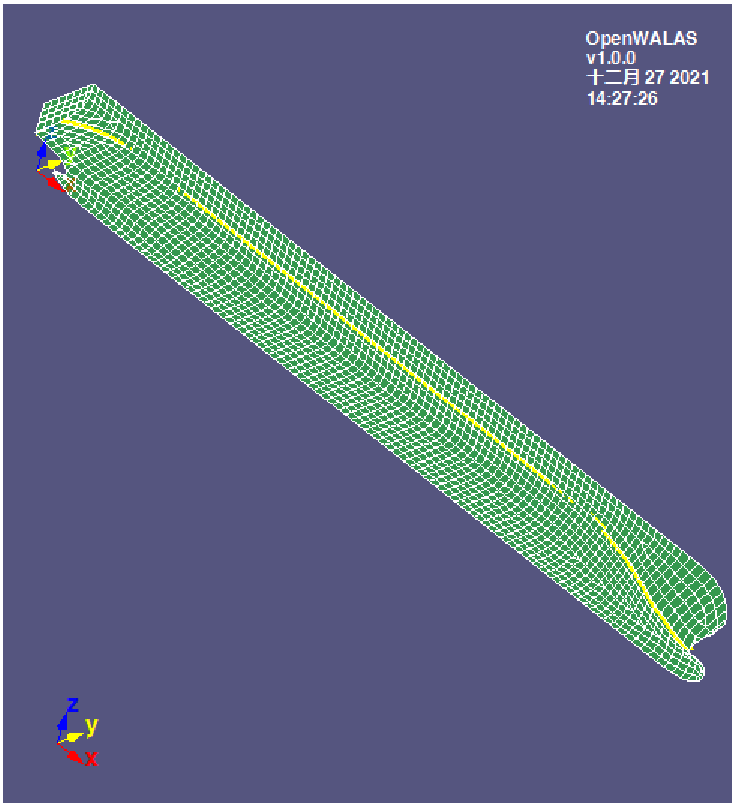


Fig. 24 Extract waterline from wet model

3.3. Create project and input parameters

3.3.1. Set working directory

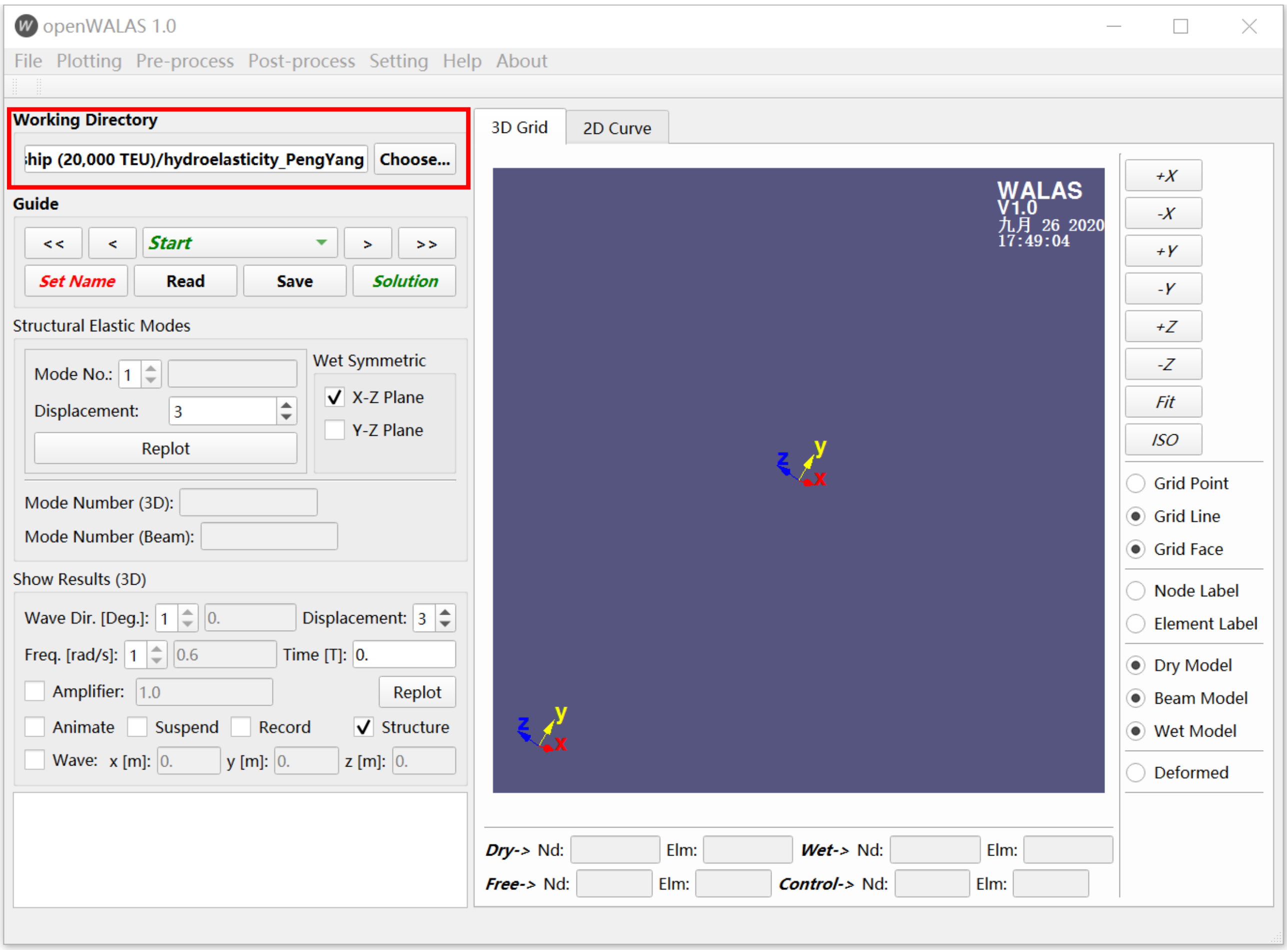
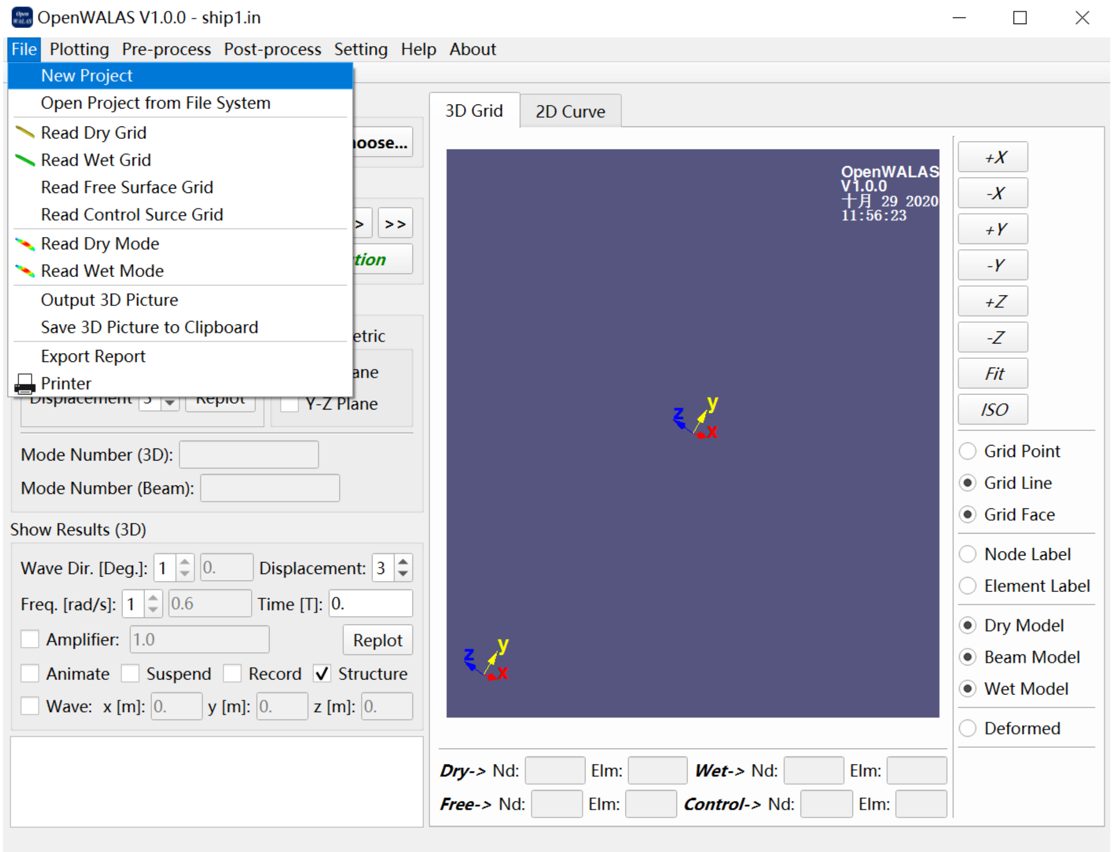


Fig. 25 Working directory

3.3.2. New Project



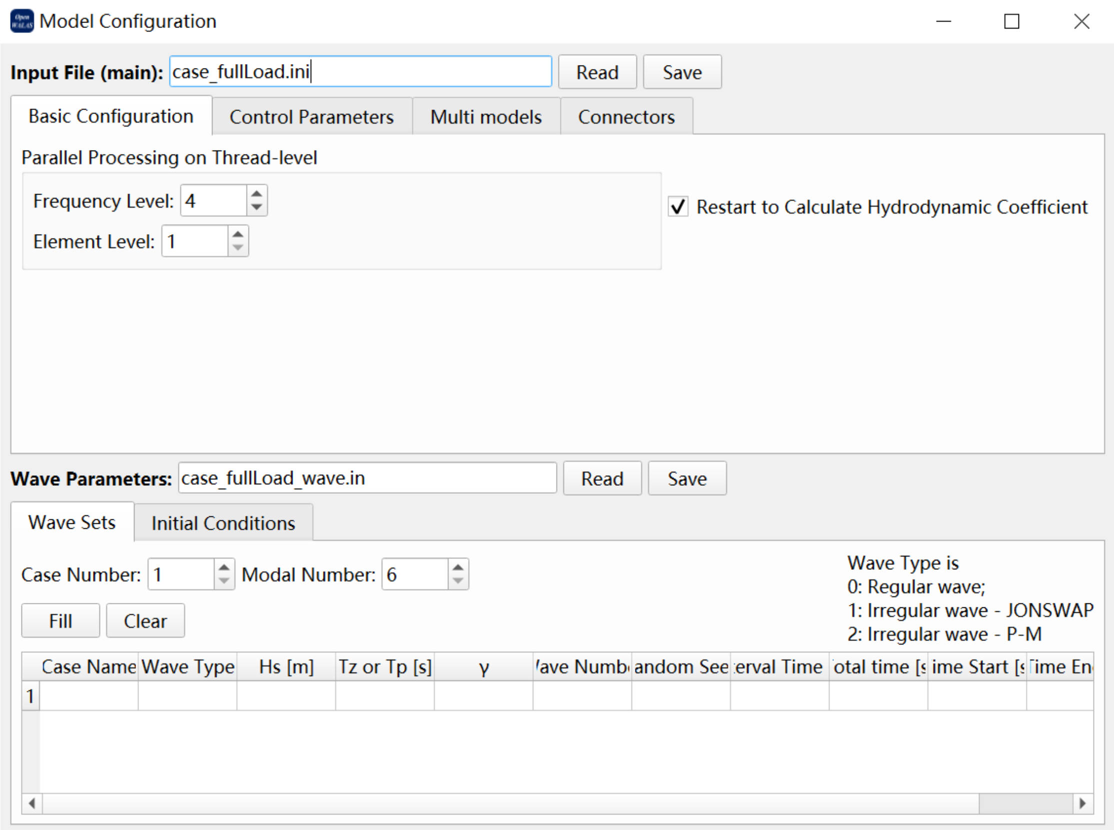


Fig. 26 Create new file of project (case.ini)

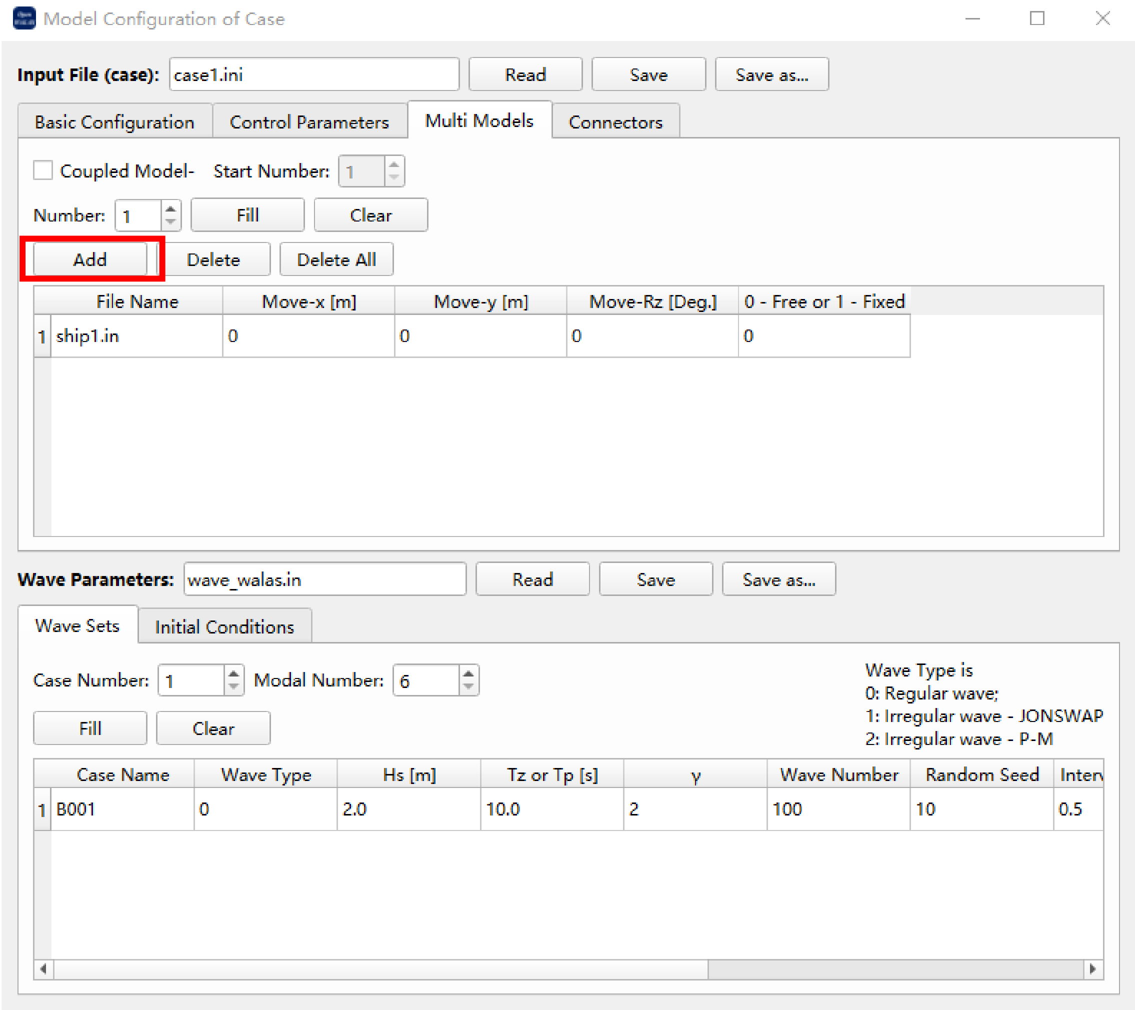


Fig. 27 Add floating structure of project

3.3.3. Set a file name of floating structure

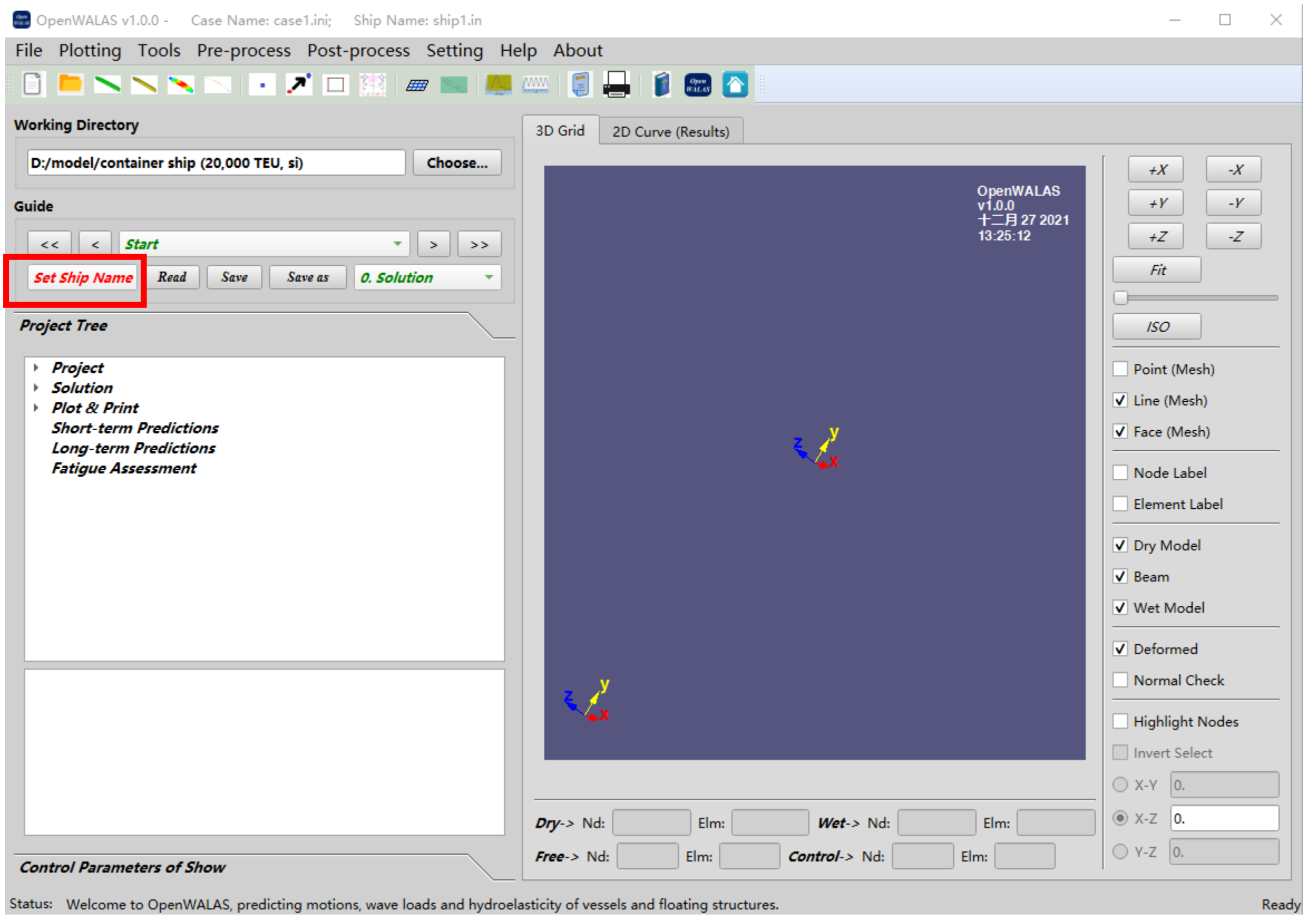


Fig. 28 Set file name

3.3.4. Step 1 - Grid Models and Elastic Modes

(1) dry model and wet model from .bdf and .f06 files of Patran

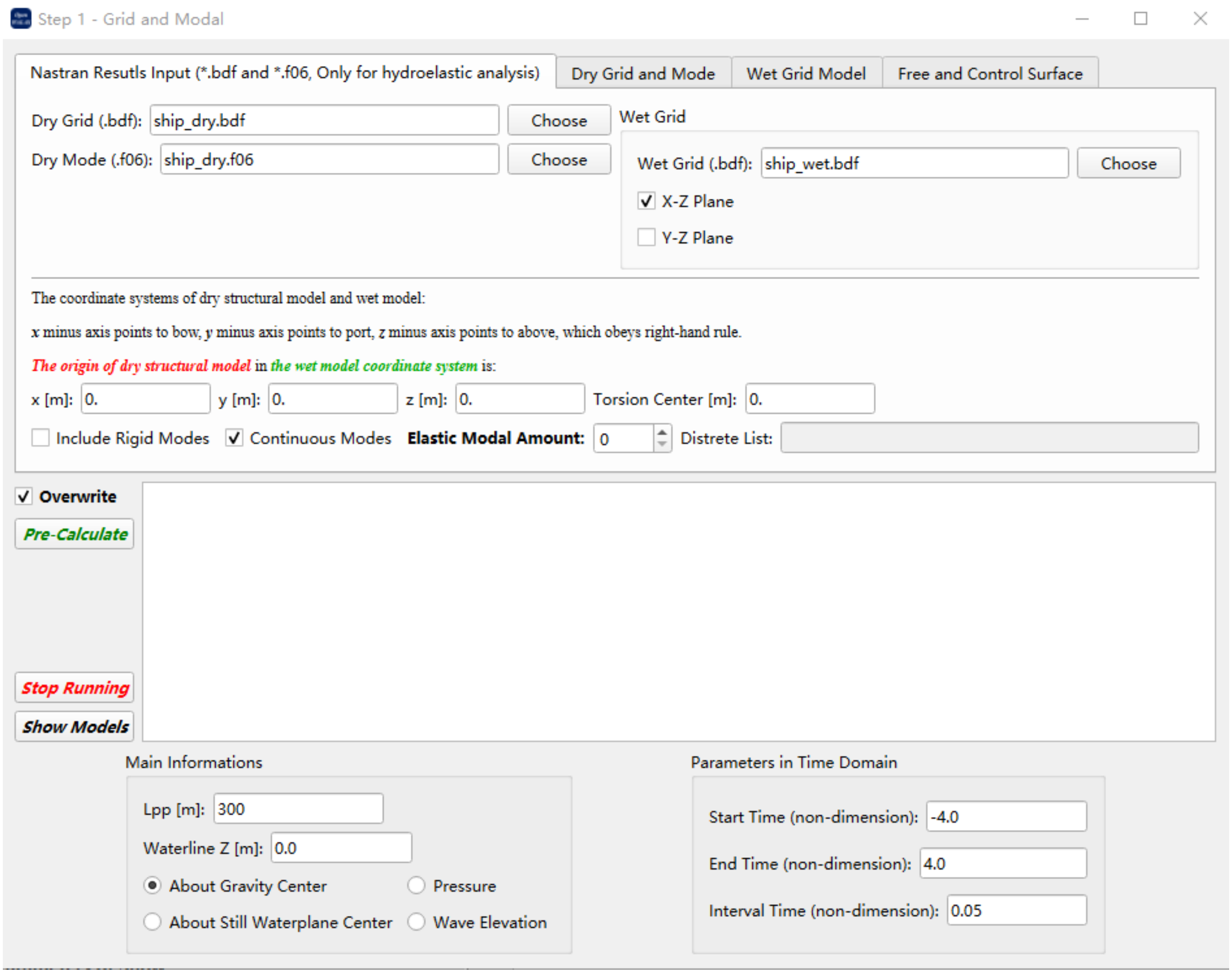


Fig. 29 Dry and wet models

(2) Free surface model and control surface model from *.bdf of Patran

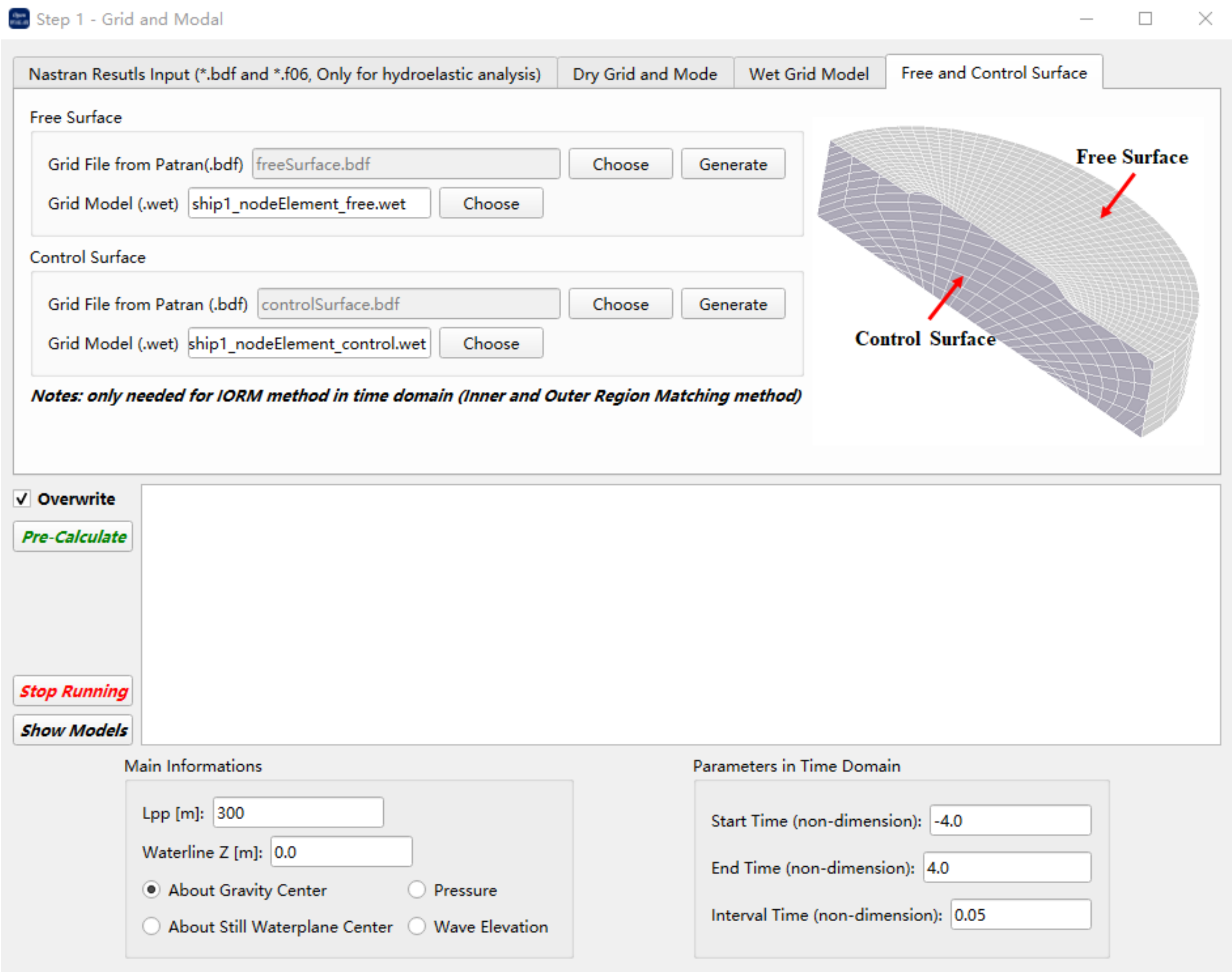


Fig. 30 Free surface and control surface models

(3) Slamming parameters

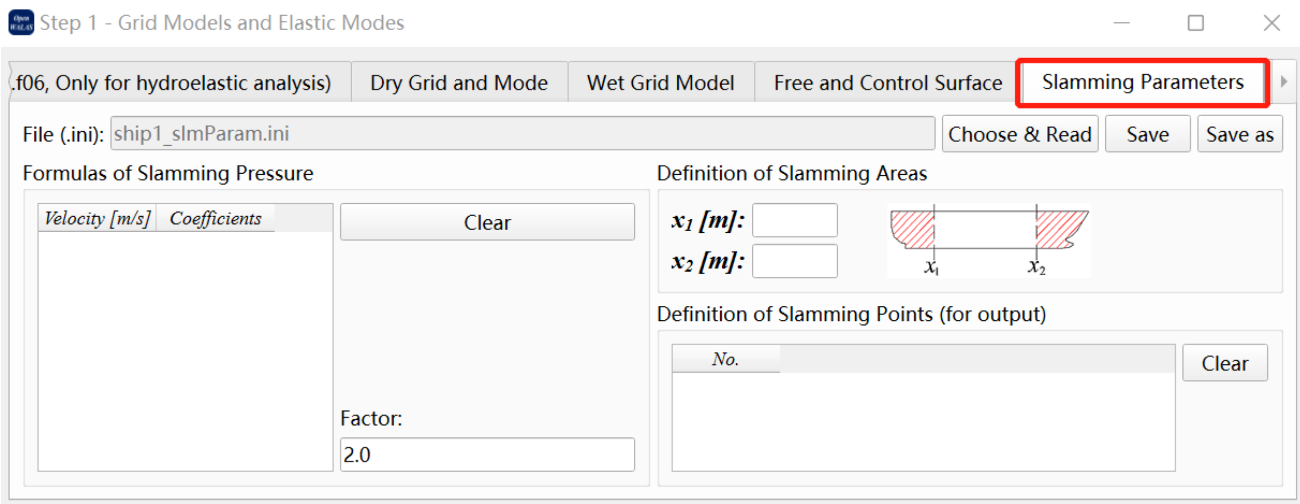


Fig. 31 Slamming parameters

3.3.5. Step 2 - Mass & Inertia

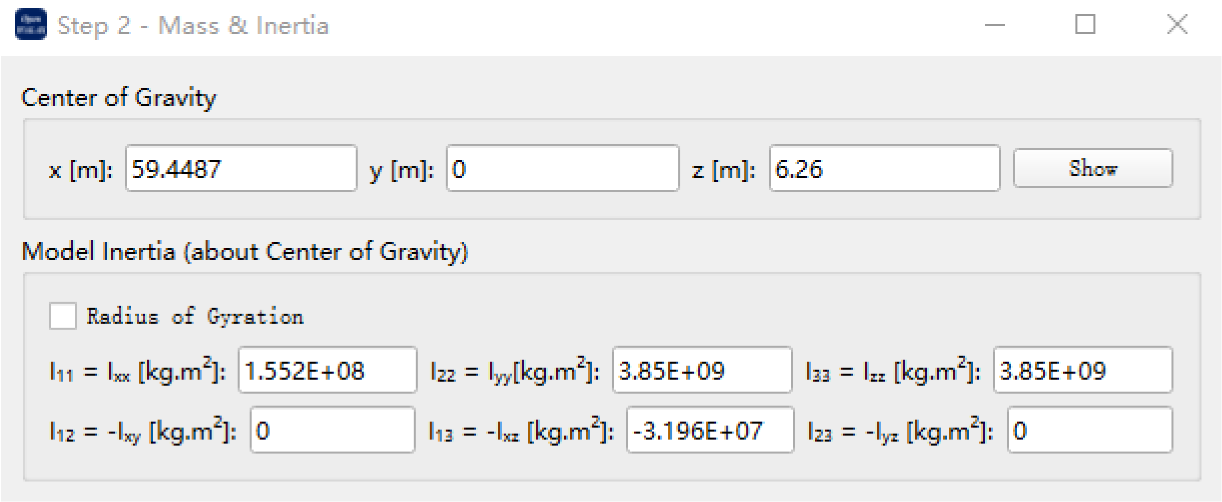


Fig. 32 Step 2

3.3.6. Step 3 - Forward Speed & Water Depth

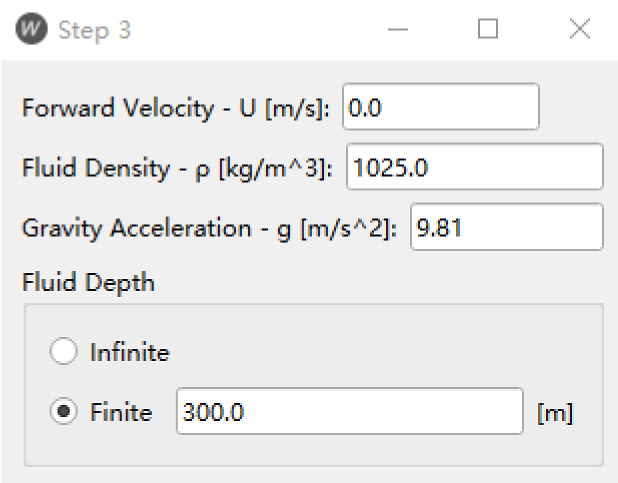


Fig. 33 Step 3

3.3.7. Step 4 - Wave Frequencies & Periods

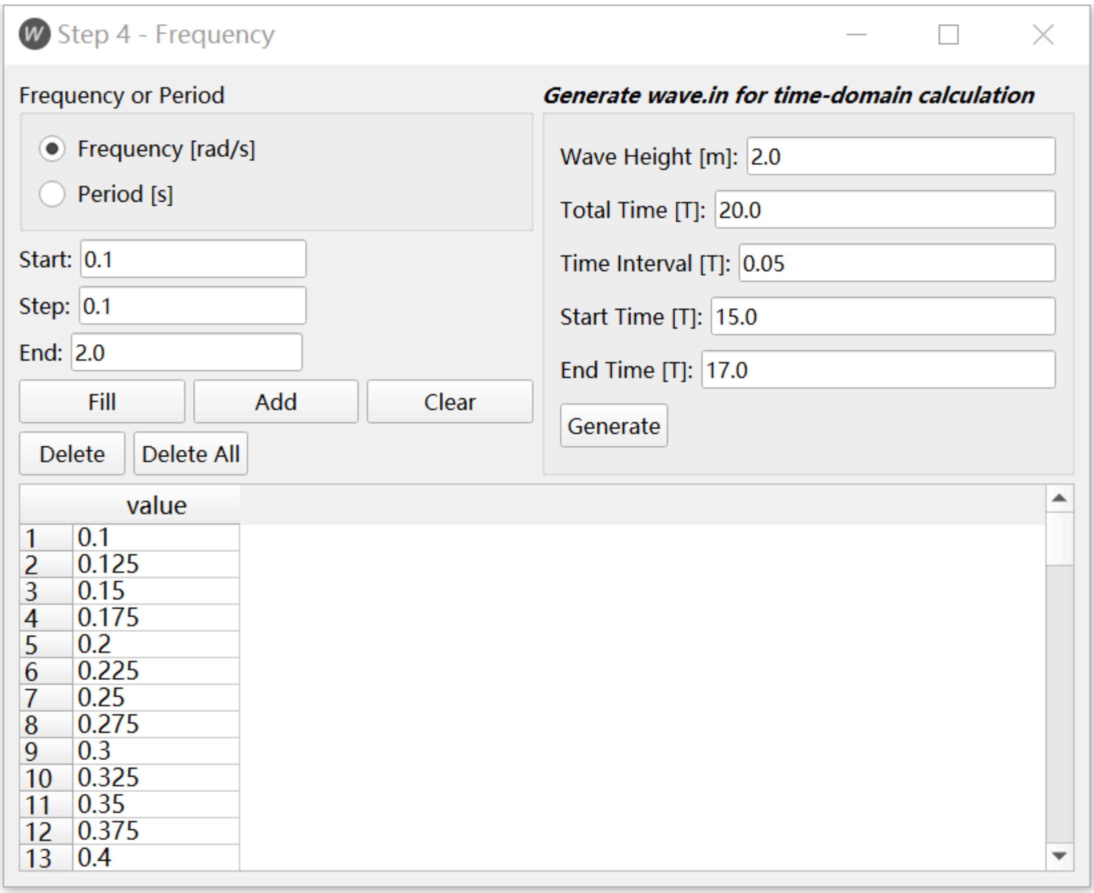


Fig. 34 Step 4

3.3.8. Step 5 - Wave Directions

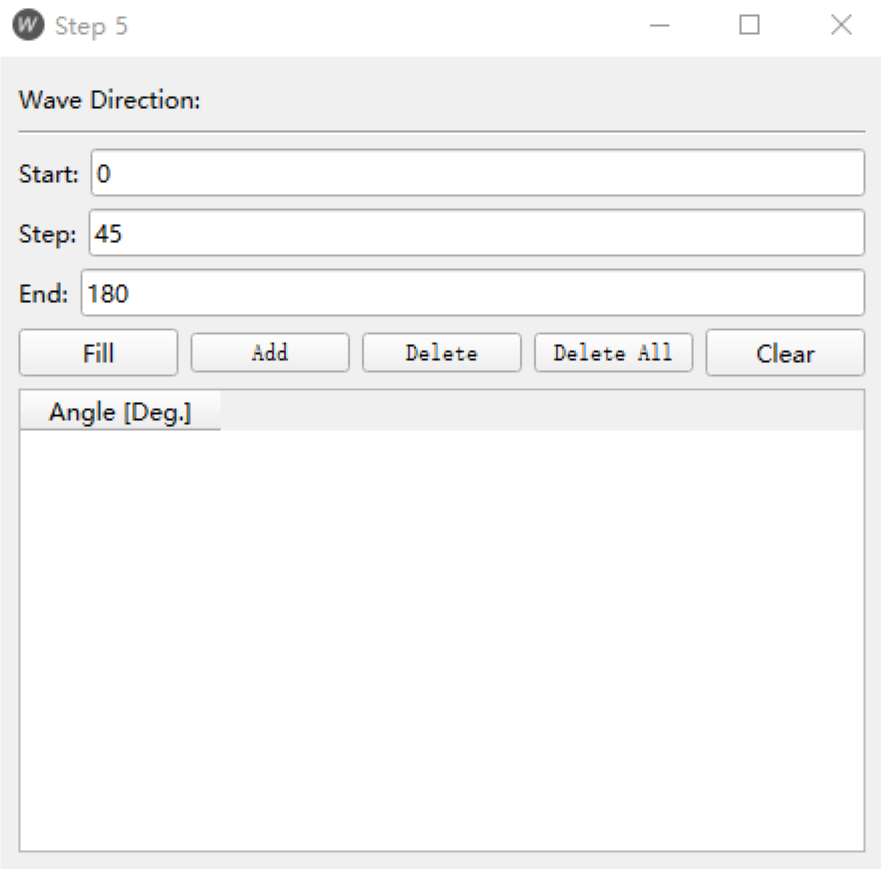


Fig. 35 Step 5

3.3.9. Step 6 - Artificial Viscous Damping

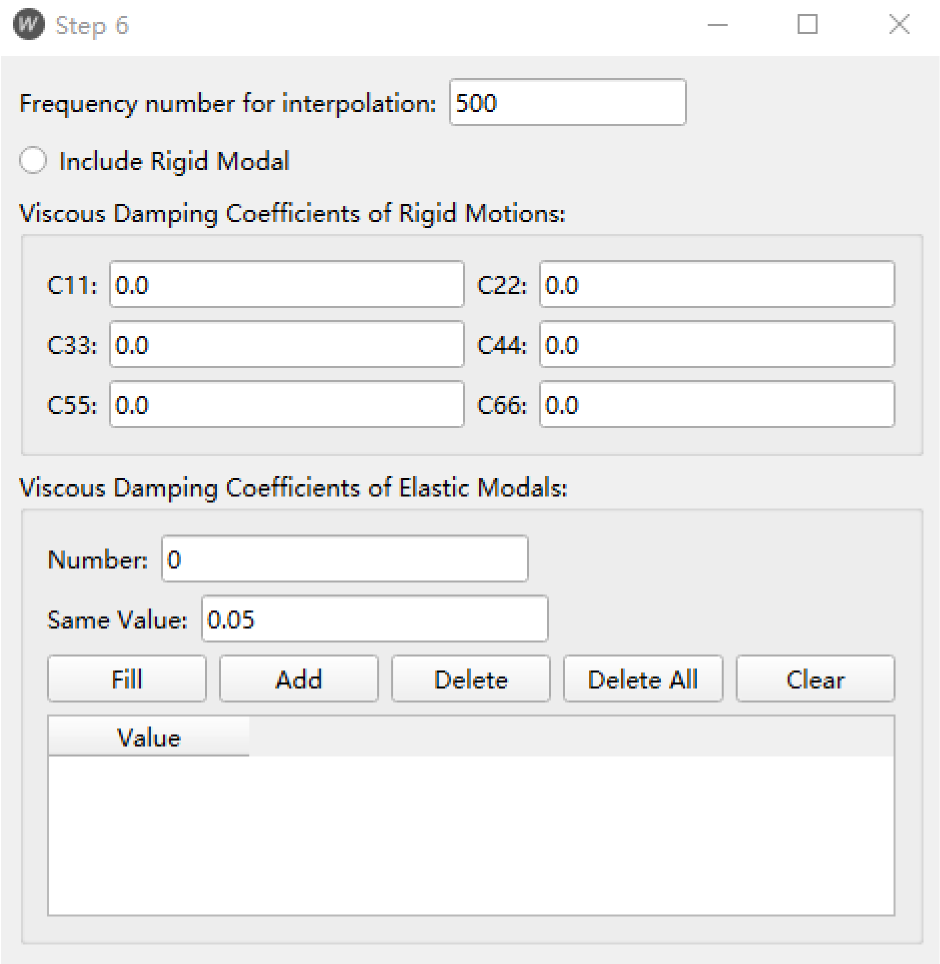


Fig. 36 Step 6

3.3.10. Step 7 - Wave Loads of Mass Distribution and Sections

When calculating the bending moment of different sections， minus moment and plus moment denote the sagging moment and hogging moment for integral of bow part, respectively. And, the opposite sign is for the integral of stern part.

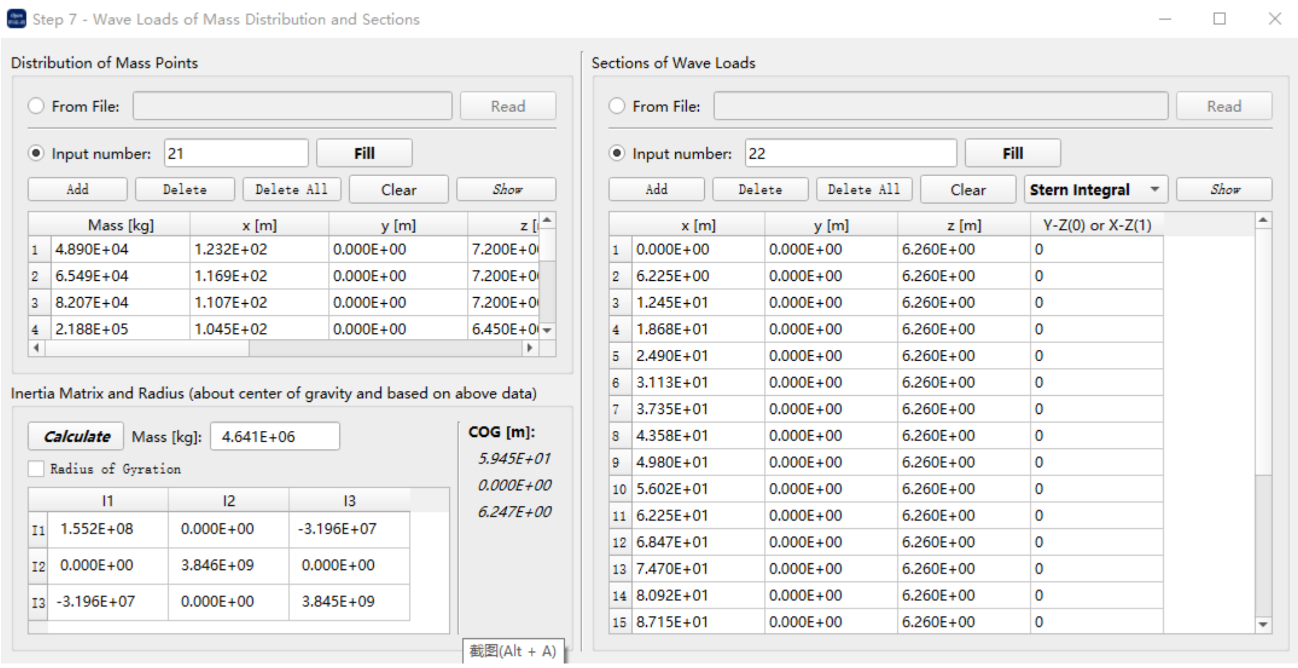


Fig. 37 Step 7

3.3.11. Step 8 - Springs & Mooring Lines

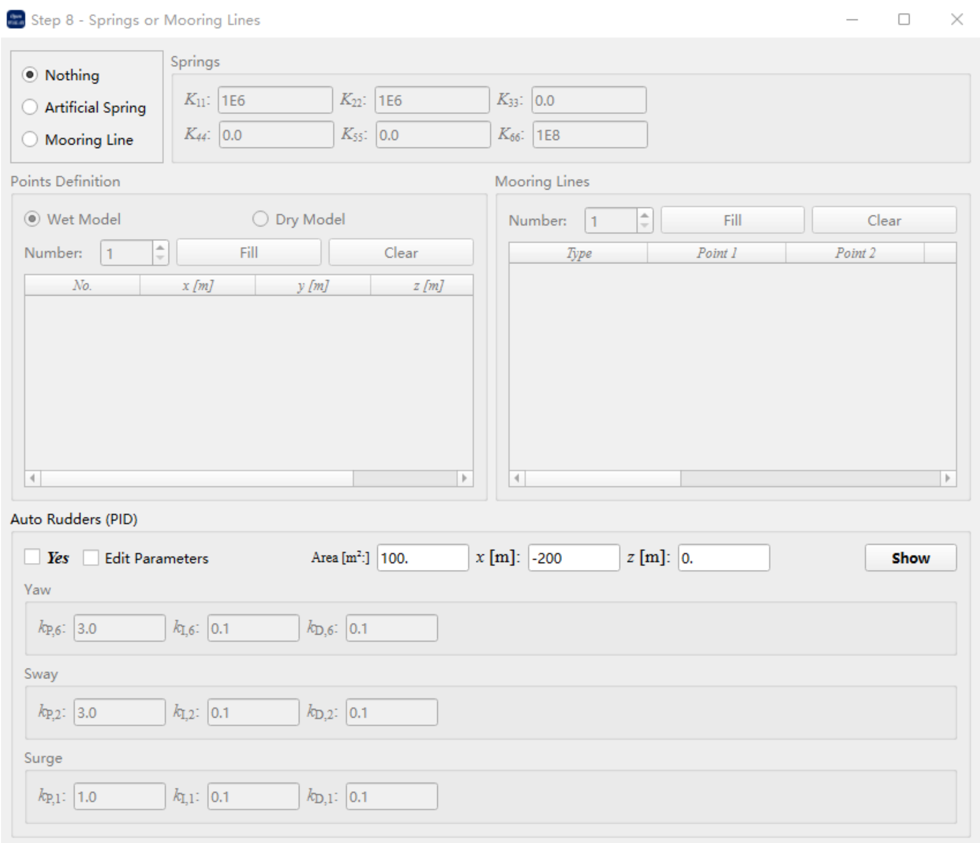


Fig. 38 Step 8

3.3.12. Step 9 - Other Parameters

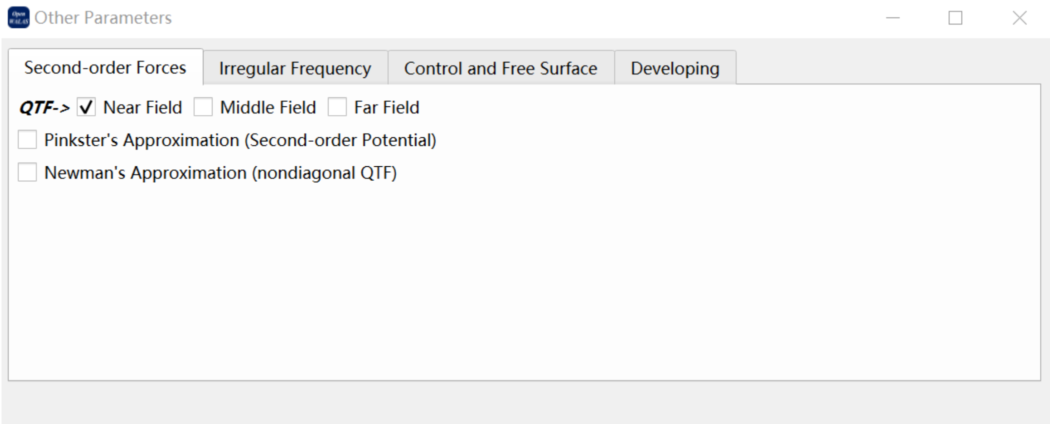


Fig. 39 Step 9 (SECOND-ORDER-FORCE)

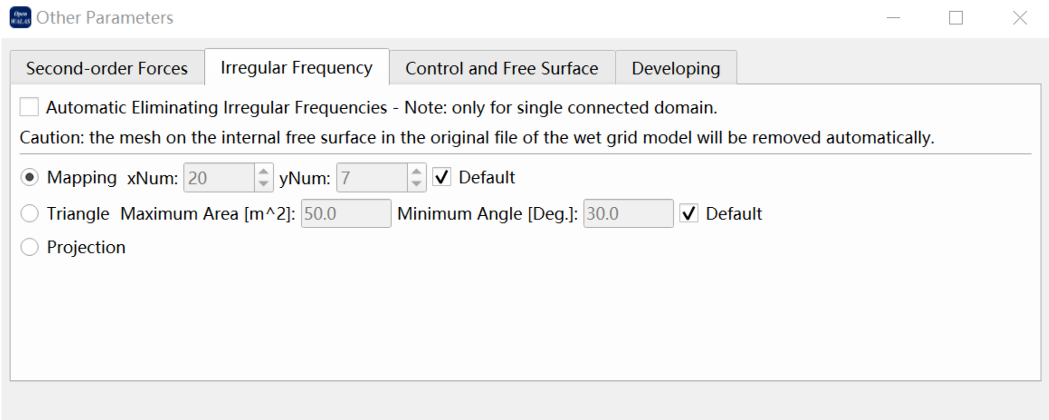


Fig. 40 Step 9 (Eliminating Irregular Frequency Automatically)

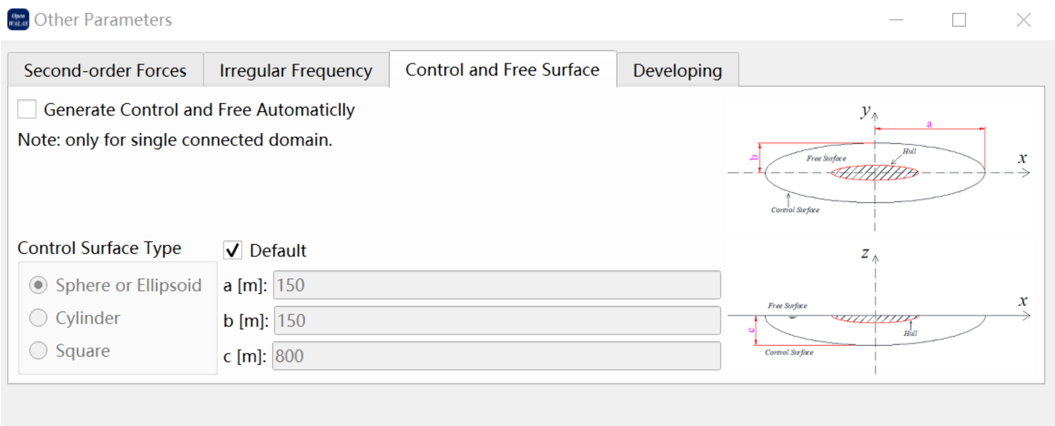


Fig. 41 Step 9 (Automatic Control and Free)

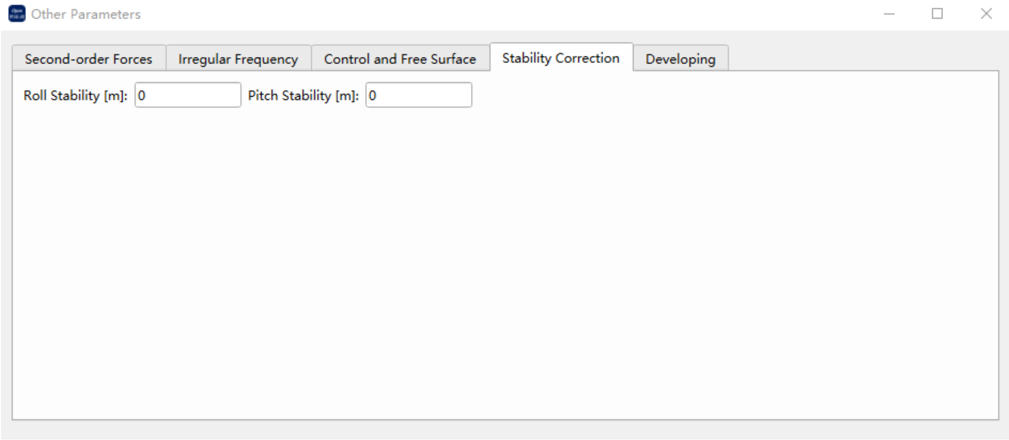


Fig. 42 Step 9 (Stability Correction)

3.4. Solution

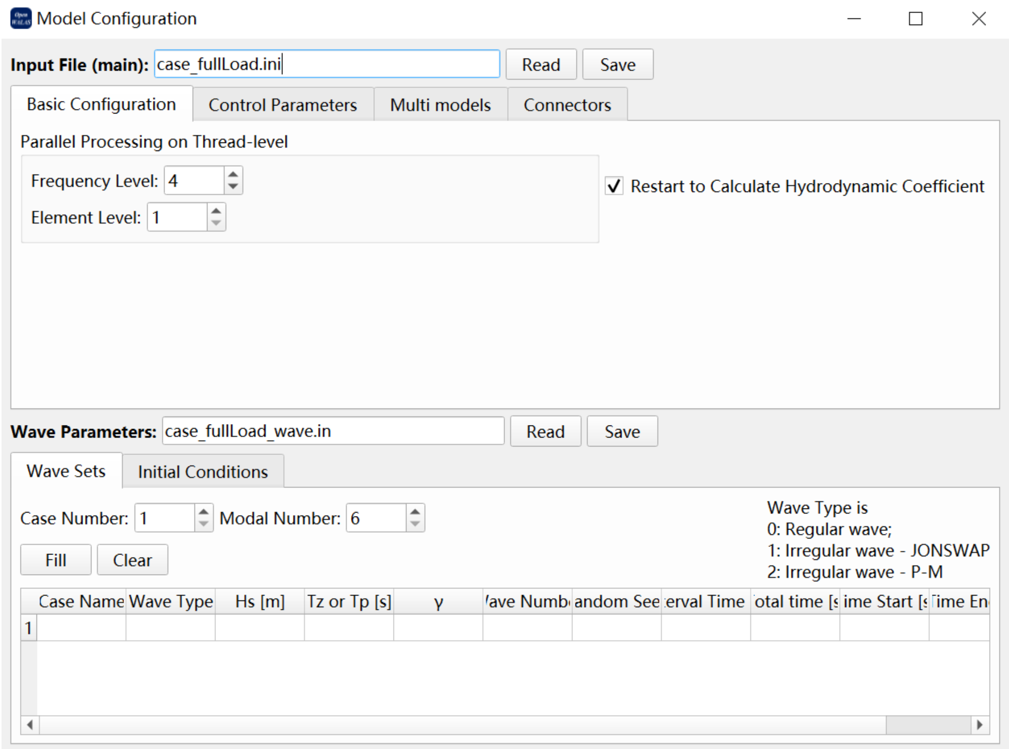


Fig. 43 Configuration of models

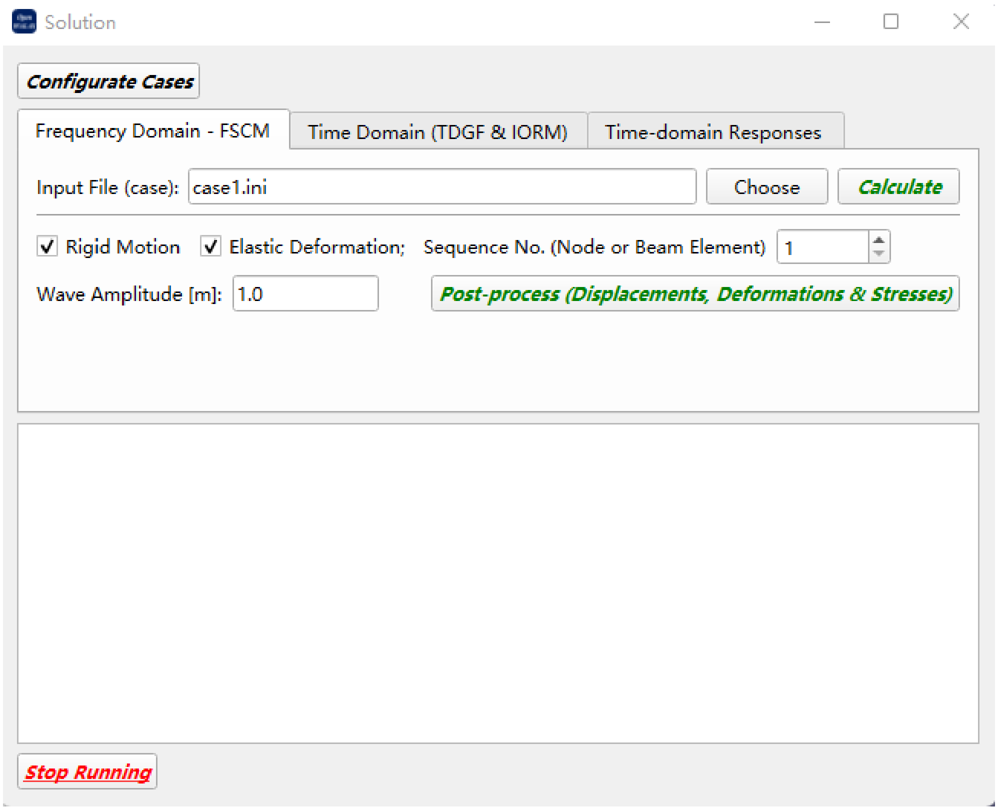


Fig. 44 Solution type

3.5. Post-process and show results

3.5.1. Basic information

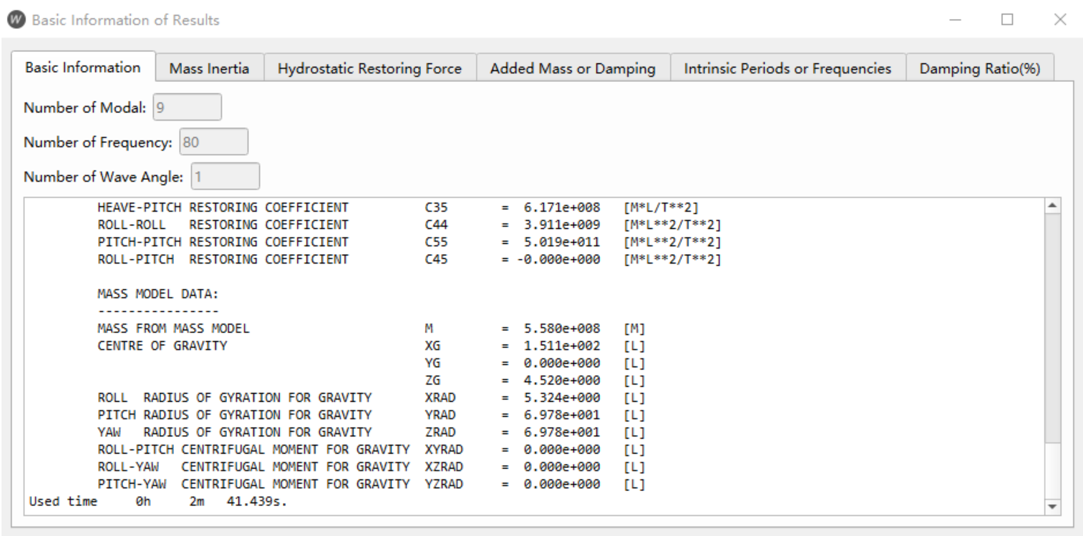


Fig. 45 Basic information

3.5.2. Results in frequency domain

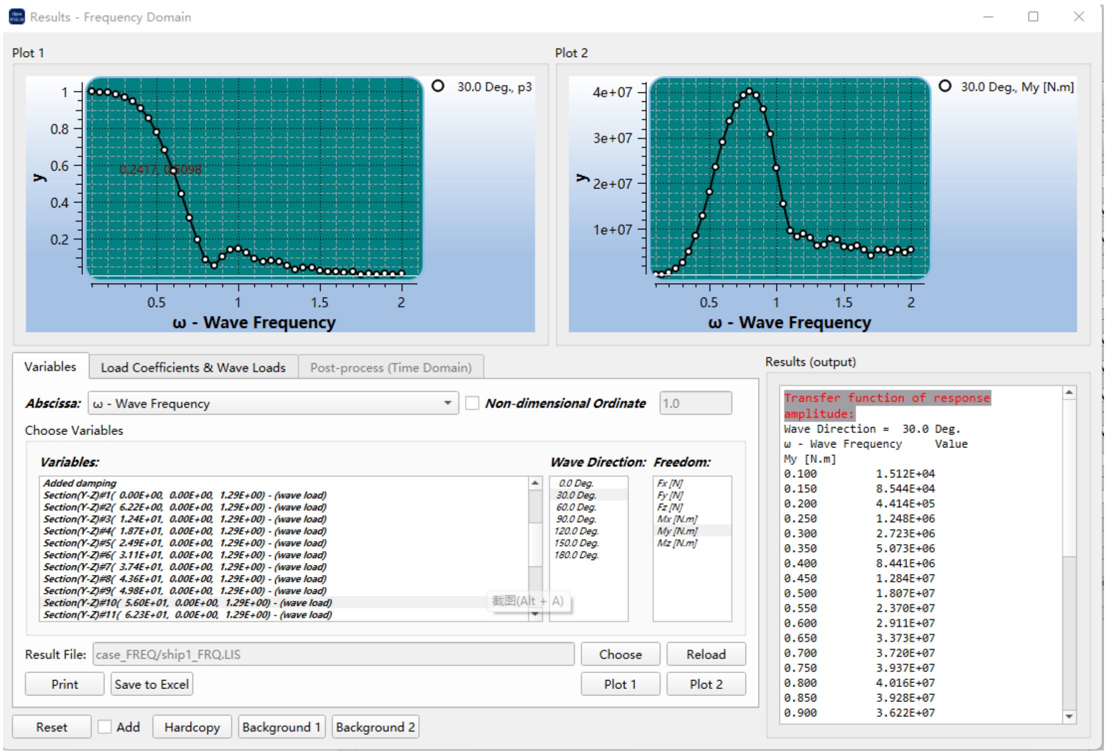


Fig. 46 Results in frequency domain

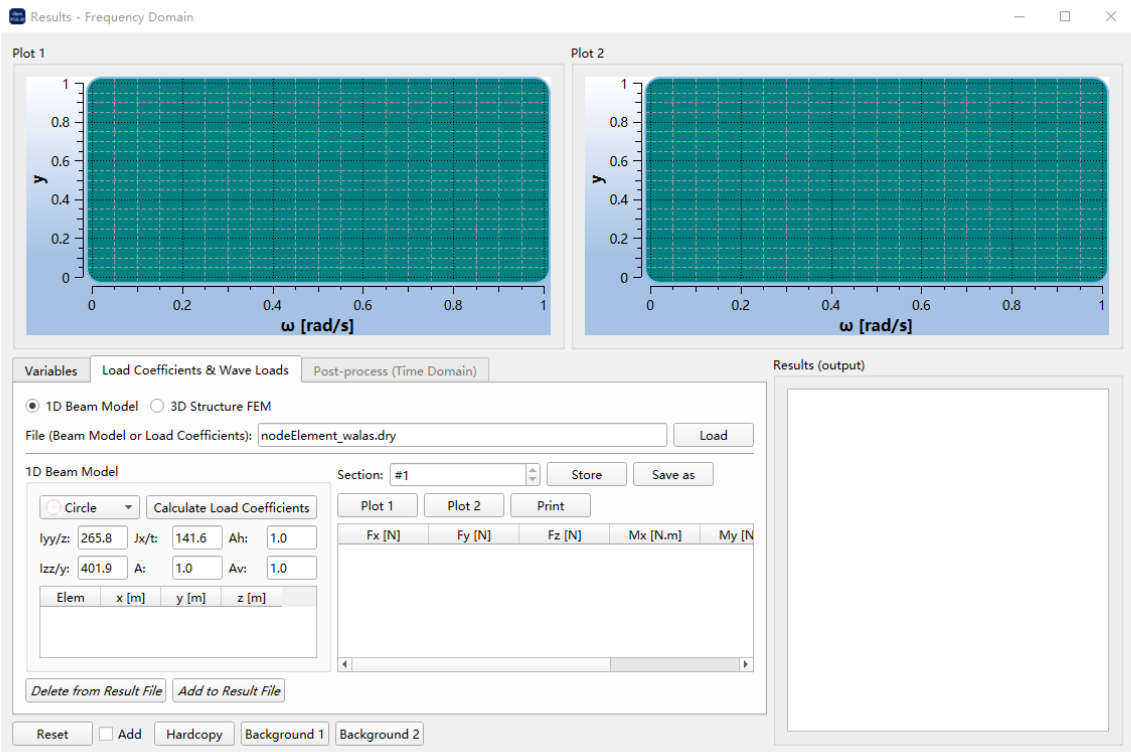


Fig. 47 Mode superposition of sectional wave loads in frequency domain

3.5.3. Results in time domain

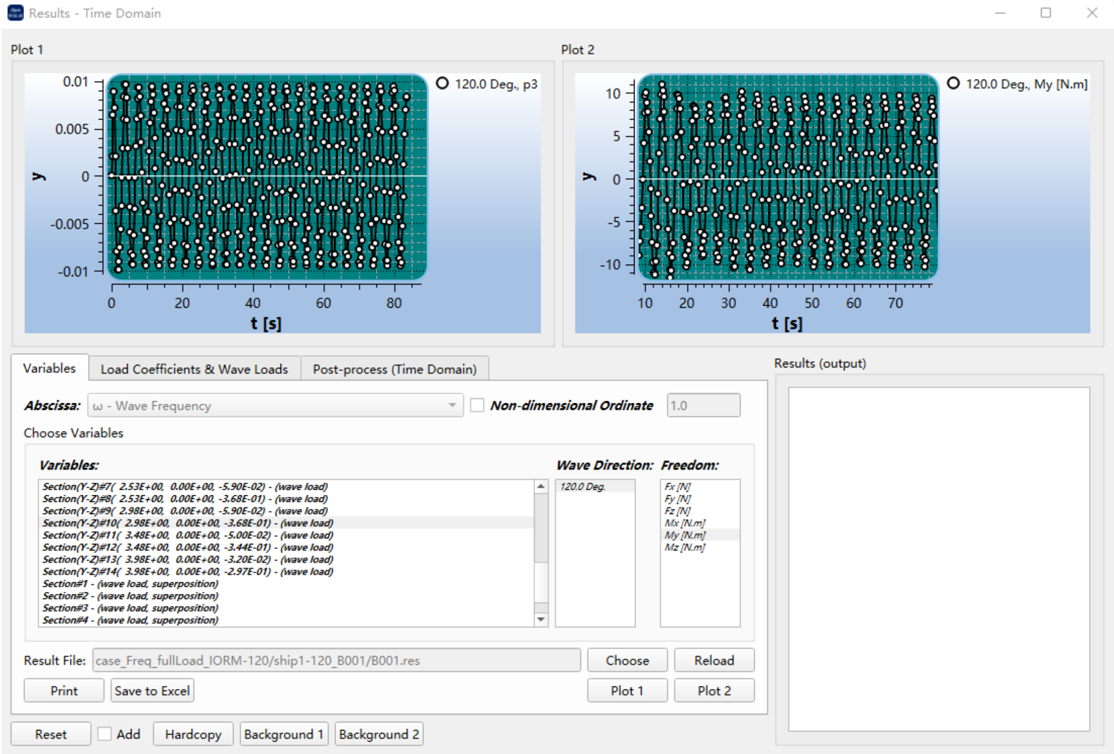


Fig. 48 Results in time domain

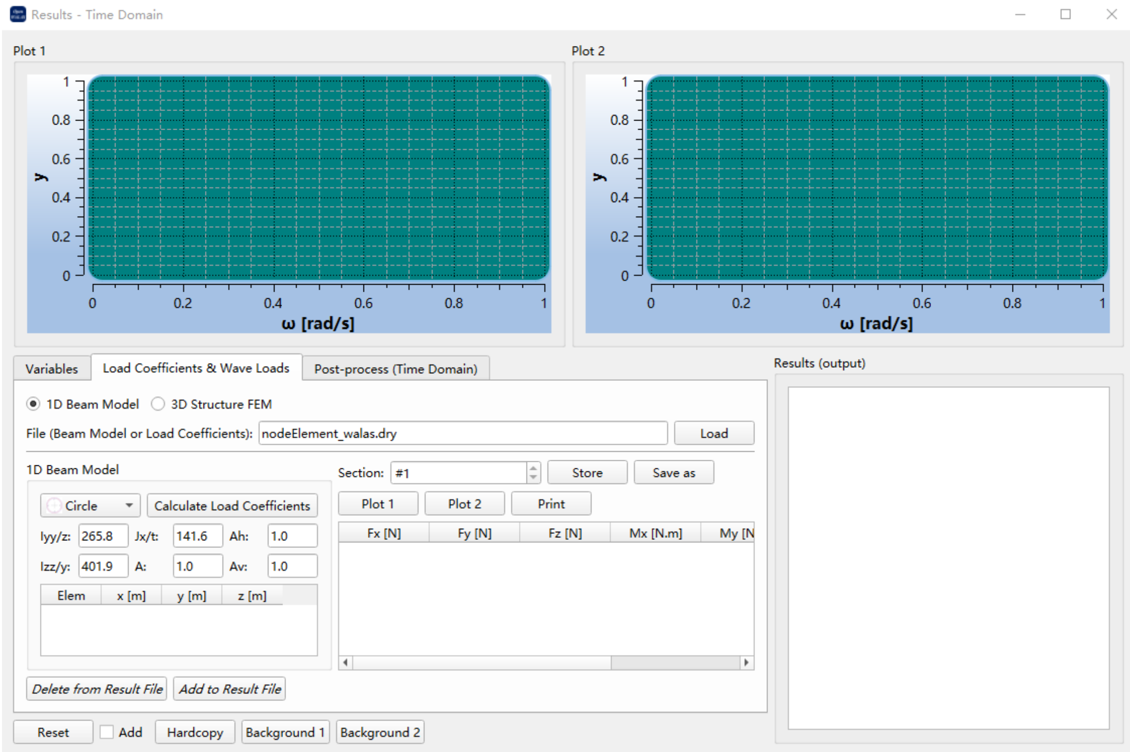


Fig. 49 Mode superposition of sectional wave loads in time domain

3.5.4. Predictions in short-term

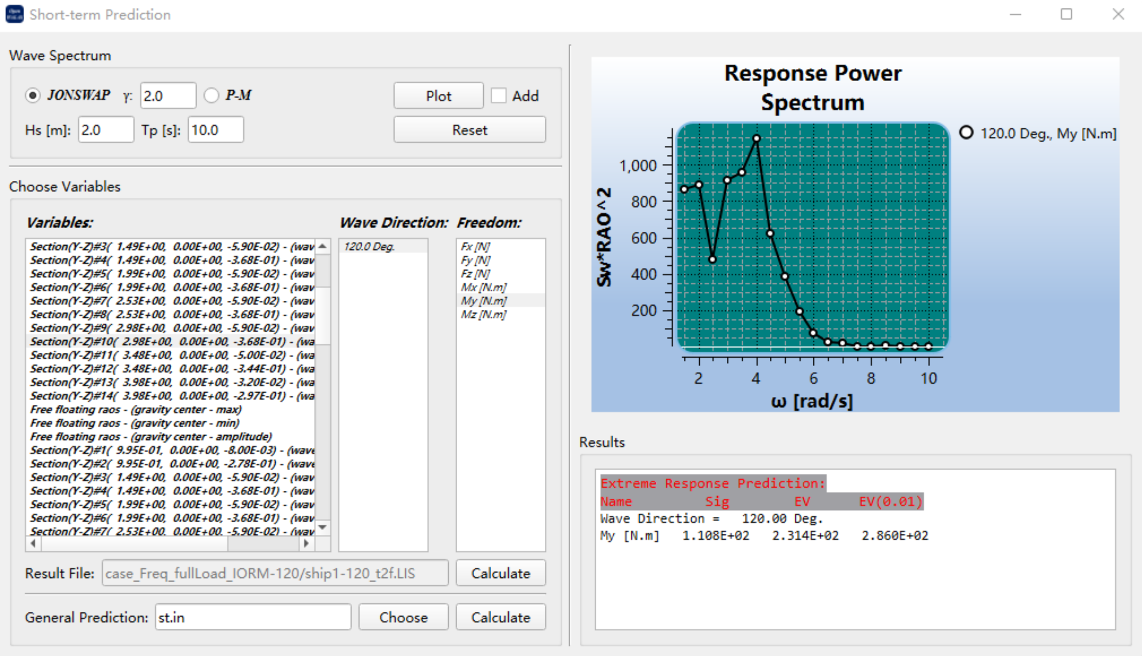


Fig. 50 Prediction in short-term

3.5.5. Predictions in long-term and fatigue analysis

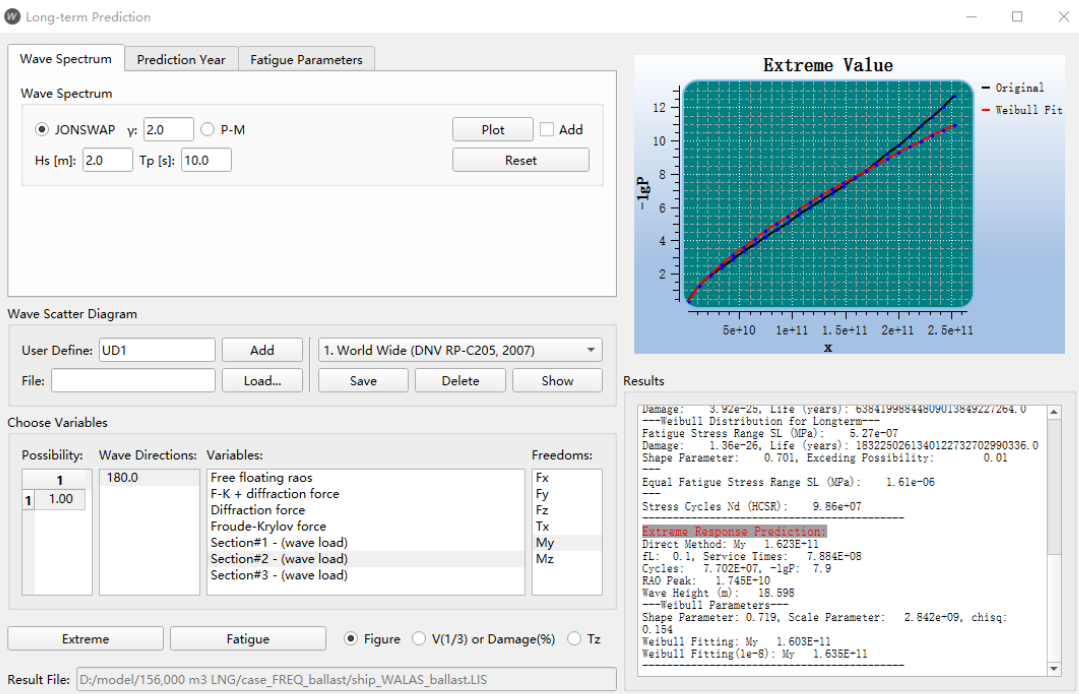


Fig. 51 Prediction in long-term

3.6. Tools

3.6.1. Natural frequency prediction of uniform straight beam

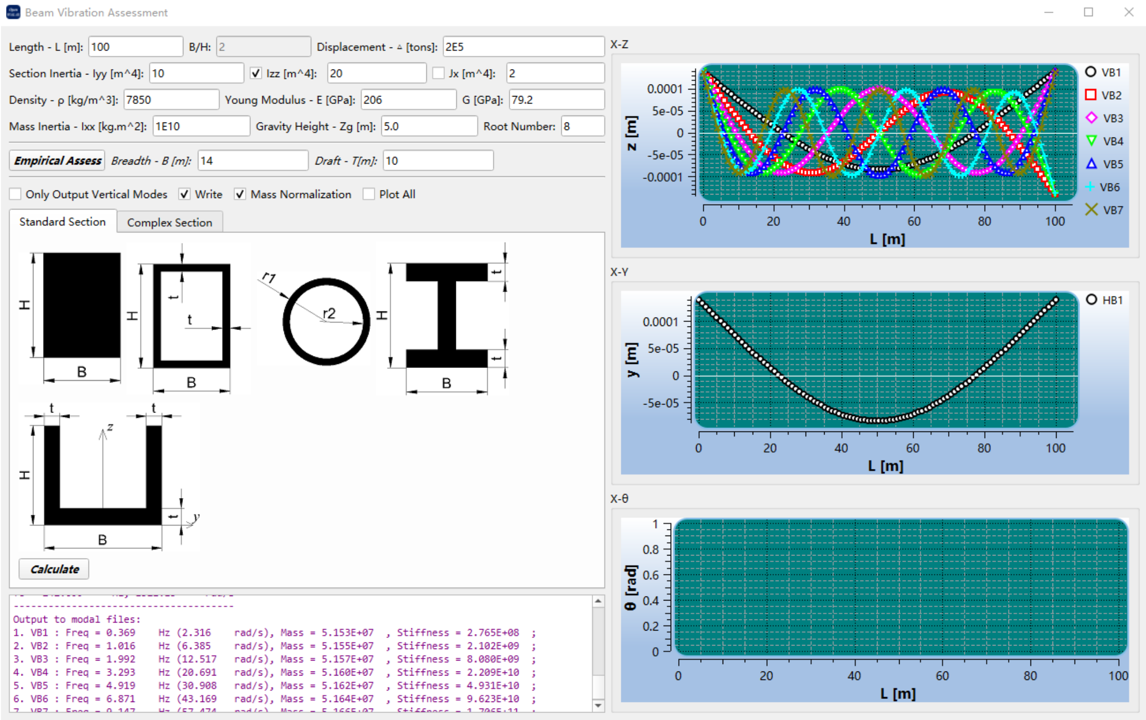


Fig. 52 Natural frequency prediction

3.6.2. Operate nodes and elements

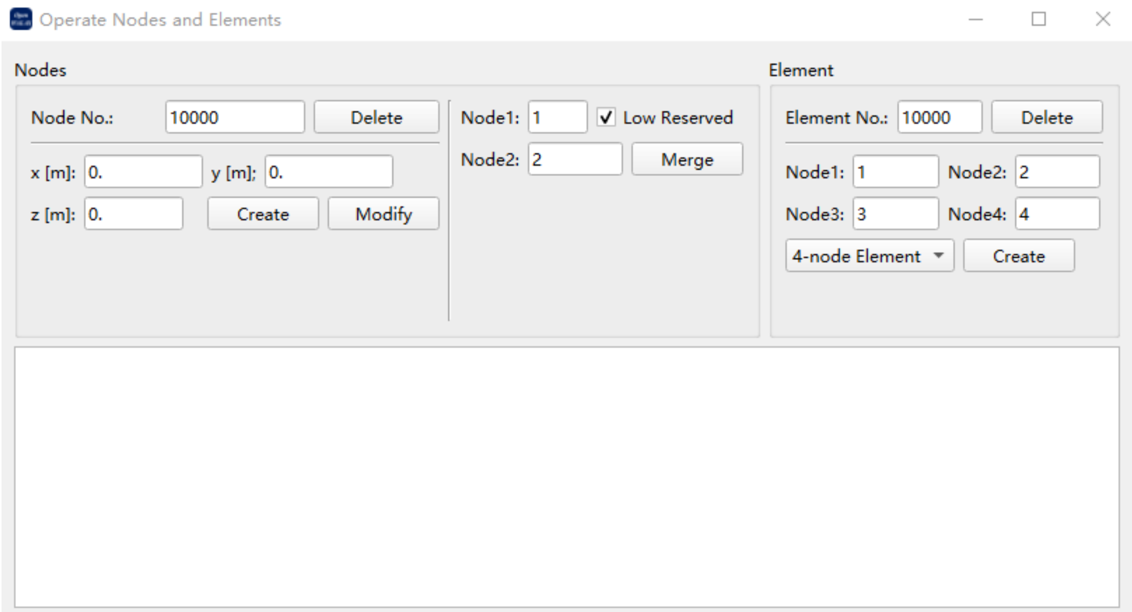


Fig. 53 Operate nodes and elements

3.7. Basic definitions

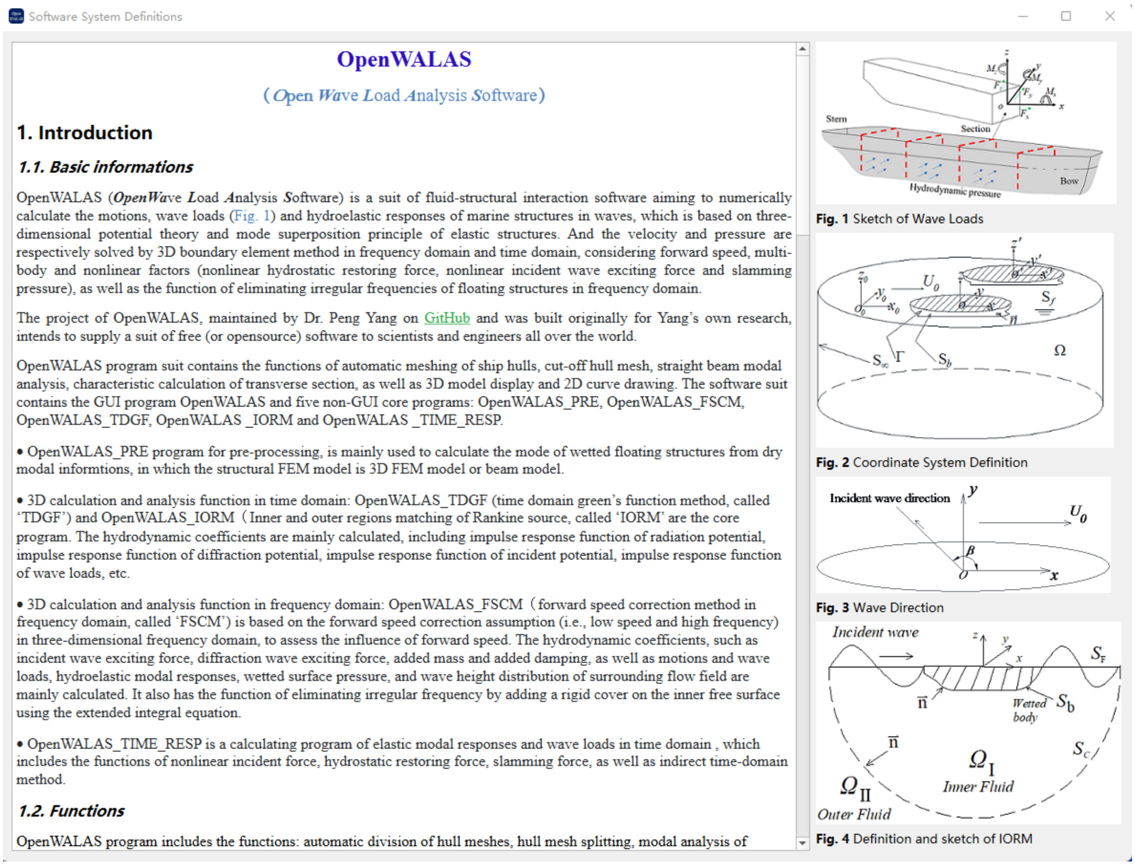


Fig. 54 Basic definition

4. Introduction of OpenWALAS non-GUI

There are five input files: *case.ini*, *ship1.in*, *wave.in*, *ship_wet.bdf*, *ship_dry.bdf*, *ship.f06*.

4.1. Running sequences

1. Three-dimensional frequency-domain calculating module: *OpenWALAS_PRE* → *OpenWALAS_FSCM*.

2. Three-dimensional indirect time-domain calculating module: *OpenWALAS_PRE* → *OpenWALAS_FSCM* → *OpenWALAS_TIME_RESP*.

3. Three-dimensional direct time-domain calculating module: *OpenWALAS_PRE* → *OpenWALAS_TDGF* or *OpenWALAS_IORM* → *OpenWALAS_TIME_RESP*.

4.2. Input parameters of running

4.2.1. Pre-processing

OpenWALAS_PRE [Case name] [Flag]

Case name: the name of the case, such as *case.ini*

Flag: the flag of overwrite the files, 0 – No, 1 – Yes

4.2.2. Solution

(a) Three-dimensional method in frequency domain

OpenWALAS_FSCM [*Case name*]

Case name: the name of the case, such as *case.ini*

(b) Three-dimensional method to calculate hydrodynamic coefficients in time domain (TDGF)

OpenWALAS_TDGF [*Case name*]

Case name: the name of the case, such as *case.ini*

(c) Three-dimensional method to calculate hydrodynamic coefficients in time domain (IORM)

OpenWALAS_IORM [*Case name*]

Case name: the name of the case, such as *case.ini*

(d) Three-dimensional method to calculate modal responses, motions and wave loads in time domain (IORM)

OpenWALAS_ TIME_RESP [*Case name*] [*Wave name*]

Case name: the name of the case, such as *case.ini*

Wave name: the name of the wave parameters, such as *wave.in*

4.2.3. Post-processing

OpenWALAS_POST [*Case name*] *[Wave amplitude] [Object number] [Flag1] [Flag2]*

(i) Case name: the name of the case, such as case.ini

(ii) *Wave amplitude [m]*: the amplitude of the regular wave

(iii) Object number: the true number of node or beam element for output

(iv) *Flag1*: Including rigid motion, yes or no? [yY nN]

(v) Flag2: Including elastic deformation, yes or no? [yY nN]

4.3. Main input file of different cases (case.ini)

The file of input parameters mainly includes the control parameters of the program and does not need to be modified frequently.

4.3.1. Identity of input file

JOB WALAS MULTI

4.3.2. Parameters of parallel calculation

threadNumFreq threadNumElem

threadNumFreq: thread number for parallel process (frequency parallel)

threadNumElem: thread number for parallel process (element parallel)

4.3.3. Control parameters of hydrodynamic coupling among floating structures

STRCNUM startCoupleNo

STRCNUM: module number

startCoupleNo: module No. of starting coupling

4.3.4. Control parameters of structural modes

wetDryFlag restartFlag

wetDryFlag: nodes of connectors from wet model or dry model; 0 – wet model, 1 – dry model. If there are elastic modes, the flag must be 1 (dry model).

restartFlag: Whether restart to calculate hydrodynamic coefficients, 0 – No, 1 – Yes.

4.3.5. FKI, NONLSTF, SLM

FKI: flag of incident wave exciting force, 0 – impulse response function (linear wave force）, 1

– directly pressure integral in time domain (nonlinear wave force), 2 – interpolation by the results of transfer function in frequency domain.

NONLSTF: 0 – linear hydrostatic restoring force, 1 – nonlinear.

SLM: 0 – not considering slamming effects, 1 – Yes.

4.3.6. Input parameters and file names of different floating structures

file[n]

x[n] y[n] z[n]

FIXED

Note:

file[n]: enclosed in double quotation marks.

x[n] *y*[n] *Rz*[n]: (*x*, *y*) denotes the vector of moving in X-Y plane. *Rz* denotes rotation degree about z axis based on the gravity center of floating structures (unit: degree)

FIXED: whether fixed of the floating structures, 0 - No, 1 – Yes.

4.3.7. Connector definition

CONNUM

strcNo1 pointNo1 strcNo2 pointNo2 $stiffness_x$ $stiffness_y$ $stiffness_z$ $stiffness_{Rx}$ $stiffness_{Ry}$ $stiffness_{Rz}$

CONNUM: number of connectors

strcNo1, *strcNo2*: No. of floating structures

pointNo1, *pointNo2*: Node No.

$stiffness_x$ $stiffness_y$ $stiffness_z$ $stiffness_{Rx}$ $stiffness_{Ry}$ $stiffness_{Rz}$: the stiffness of translation and rotation

4.3.8. Example

JOB WALAS MULTI

8 8

2 1

1 1

0 0 0

"ship1_half.in"

0. 0. 0.

0

"ship2_half.in"

40. 0. 0.

0

0

4.4. Input parameters of floating structures (shipX.in)

File of parameters (the most important files), including the information of models.

4.4.1. Identity

JOB WALAS

4.4.2. File name of wet grid model

Enclosed in double quotation marks

4.4.3. File name of dry grid model

Enclosed in double quotation marks

4.4.4. Modal shapes of nodes of dry model

Enclosed in double quotation marks

4.4.5. Modal shapes of elements of wet model

Enclosed in double quotation marks

4.4.6. Information of dudx of wet model

Enclosed in double quotation marks

4.4.7. File name of grid model of free surface

Enclosed in double quotation marks

Only affect for IORM method in time domain

4.4.8. File name of grid model of virtual control surface

Enclosed in double quotation marks

Only affect for IORM method in time domain

4.4.9. File name of slamming pressure

Enclosed in double quotation marks

Only affect in time domain

4.4.10. Characteristic parameters

Lpp SwlHeight ISOFLAG NORMALFLAG ORIGINFLAG PRESFlag WHPFlag nonTimeStart nonTimeEnd nonDt

Lpp: perpendicular length

SwlHeight: height of still water surface relative to wet coordinate system

ISOFLAG: symmetrical flag of wet model, 0 – no symmetry, 1 - Bilateral symmetry, 2 – two symmetrical planes about Y-Z plane and X-Z plane

NORMALFLAG: normal flag of wet model, 1 – point to internal of ship hull, -1 - point to external fluid. For Rankine source method (IORM), the normal vectors of free surface and virtual control surface are consistent with ship hull.

ORIGINFLAG: 0 denotes origin of the internal calculating coordinate system is the project of the origin of wet model on still water surface, 1 – denotes origin is gravity center.

PRESFlag: whether calculate pressure on ship hull, 0 – No, 1 – Yes.

WHPFlag: whether calculate wave height of the specific points in fluid filed, 0 – No, 1 – Yes.

nonTimeStart: nondimensional starting time.

nonTimeEnd: nondimensional end time.

nonDt: nondimensional interval time.

4.4.11. Coordinates of gravity center

Xg Yg Zg

Relative to wet coordinate system

Xg: *x* value

Yg: *y* value

Zg: *z* value

4.4.12. Mass inertia

I_{11} I_{22} I_{33} I_{12} I_{13} I_{23}

Relative to gravity center

I_{11}: about x axis, $I_{11}=I_{xx}=\int x^2 \mathrm{d}m$;

I_{22}: about y axis, $I_{22}=I_{yy}=\int y^2 \mathrm{d}m$;

I_{33}: about z axis, $I_{33}=I_{zz}=\int z^2 \mathrm{d}m$;

I_{12}: in x-y plane, $I_{12}=I_{21}=-I_{xy}=-\int xy\mathrm{d}m$;

I_{13}: in x-z plane, $I_{13}=I_{31}=-I_{xz}=-\int xz\mathrm{d}m$;

I_{23}: in y-z plane, $I_{23}=I_{32}=-I_{yz}=-\int yz\mathrm{d}m$;

$$[M]=\begin{bmatrix} m & 0 & 0 & 0 & mz_g & -my_g \\ 0 & m & 0 & -mz_g & 0 & mx_g \\ 0 & 0 & m & my_g & -mx_g & 0 \\ 0 & -mz_g & my_g & I_{11} & I_{12} & I_{13} \\ mz_g & 0 & -mx_g & I_{21} & I_{22} & I_{23} \\ -my_g & mx_g & 0 & I_{31} & I_{32} & I_{33} \end{bmatrix}$$

4.4.13. Position of dry coordinate origin in wet coordinate system

x_{Dry} y_{Dry} z_{Dry} Tz

x_{Dry}: x value

y_{Dry}: y value

z_{Dry}: z value

Tz: torsional center (or shear center) relative to neutral axis of vertical bending (only works in 1D beam model); above the neutral axis the value is positive, and below the neutral axis the value is negative.

4.4.14. Forward speed, density and acceleration of gravity

Vel Rho G

Forward speed, density of fluid, gravity acceleration.

4.4.15. Water depth

DepthFlag Depth

DepthFlag: flag of water depth, 0 – finite water depth, 1 – infinite water depth

Depth: water depth, only works in finite water depth case

4.4.16. Frequencies or periods

FreqFlag FreqNum

[FreqStar tFreqEnd] [Freq1 Freq2 Freq3 ……] *(six in a row)*

FreqFlag: flag of frequencies, 0 - continuous values, 1 - discrete values

FreqNum: number of frequencies

FreqStart: starting value, only works when FreqFlag is 0.

FreqEnd: end value, only works when FreqFlag is 0.

Freq[*n*]: values, only works when FreqFlag is 1.

4.4.17. Wave directions

DirFlag DirNum

[DirStart DirEnd] [Dir1 Dir2 Dir3 ……] *(six in a row)*

DirFlag: flag of wave directions, 0 - continuous values, 1 - discrete values

DirNum: number of wave directions

DirStart: starting value, only works when DirFlag is 0

DirEnd: end value, only works when DirFlag is 0.

Dir[*n*]: values, only works when DirFlag is 1.

4.4.18. Number of frequencies for interpolation

MoreFreqNum

Number of frequencies for interpolation, using spline interpolation hydrodynamic coefficient, wave excitation force, and then to solve the modal principal coordinate response results

4.4.19. Number of elastic modes

RigidFlag ElasFlag ElasNum

[Elas1 Elas2 Elas3 Elas4 Elas5 ……]

RigidFlag: flag of rigid modes, 0 – the rigid modes are not included in the modal shape files and automatic generated by programs, suggested value; 1 - Yes

ElasFlag: flag of elastic modes, 0 – continuous modal No, 1 – discrete No.

ElasNum: number of elastic modes

Elas[n]: values, only works for ElasFlag = 1.

4.4.20. Artificial damping coefficients

DampFlag1 DampFlag2

Damp1 Damp2 Damp3 ……

DampFlag1: flag of damping, 0 – ratio, 0 - coefficients

DampFlag2: flag of damping, 0 – same value, 1 – different values

Damp[*n*]: values

4.4.21. Mass points for wave loading calculations

massPointNum

mass[n] x[n] y[n] z[n] Ixx[n] Iyy[n](optional) *Izz[n]*(optional)

……

massPointNum: number of mass points, 0 – not calculate wave loads.

mass[n]: mass of each point

x[n] y[n] z[n]: coordinate about wet model

Ixx[n] Iyy[n] Izz[n]: the mass inertia about *mass point n*.

4.4.22. Section definitions of wave loads

secNum waveLoadSymbol

x [n] y[n] z[n] flag[n]

(1) *secNum*: section number of wave loads

(2) *waveLoadSymbol*: flag of integral for wave loads;

Y-Z plane: -1 - bow, 1 – stern, 0 – bow integral for sections before center of gravity and stern integral for section after center of gravity automatically. In the internal calculation of the software, for the cases of bow-integral, the vertical bending moment of the ***sagging*** state is ***negative***; the vertical bending moment of the ***hogging*** state is ***positive***, that are on the contrary for the cases of stern-integral. For the final output, sagging – '-' and hogging – '+'.

X-Z plane: -1 - port, 1 – star, 0 – port-integral for sections before center of gravity and star-integral for section after center of gravity automatically. In the internal calculation of the software, for the cases of port-integral, the vertical bending moment of the ***sagging*** state is ***negative***; the vertical bending moment of the ***hogging*** state is ***positive***, that are on the contrary for the cases of star-integral. For the final output, sagging – '-' and hogging – '+'.

(3) *x[n] y[n] z[n]*: coordinate of calculating origin

(4) *flag[n]: flag of section*, 0 (default): Y-Z transverse plane; 1: X-Z longitudinal plane

4.4.23. Spring or mooring line (*optional*)

Using artificial springs or mooring lines to control the horizontal drift (surge, sway and yaw) in time-domain calculation.

(1) *Flag*

Flag: SPRING-MOORLINE

(2) *MRL*

MRL: number or flag of mooring line; -1 – directly six springs of linear stiffness; 0 - not consider springs.

(3) *moorPointFixedNum*, *wetDryFlagMoor*

moorPointFixedNum: number of mooring points

wetDryFlagMoor: type of mooring points, 0 – from wet model, 1 – from dry model.

(4) Detailed parameters

(i) stiffness of the artificial springs in the six rigid motions

$Stiffness_x$, $Stiffness_y$, $Stiffness_z$, $Stiffness_{Rx}$, $Stiffness_{Ry}$, $Stiffness_{Rz}$

Or

(ii) parameters of mooring line

1 x1 y1 z1

2 x2 y2 z2

…

n xn yn zn

1 no type nos noe stiffness len Te Te rho

2 no type nos noe stiffness len Te Te rho

…

n no type nos noe stiffness len Te Te rho

Explanation:

no: the sequence number of mooring line;

type: the type of mooring line, 1 – rope, 2 – chain;

nos: the start point of the mooring line, on the seabed;

noe: the end point of the mooring line, on the vessel (wet grid model or dry grid model);

stiffness: the stiffness of the mooring line;

len: the length of the mooring line;

Te: the breaking force of the mooring line;

rho: the line density of the mooring line;

4.4.24. RUDDER-PID (*optional*)

Using rudder and PID method to control the horizontal drift (surge, sway and yaw) in time-domain calculation.

(1) *Flag*

Flag: RUDDER-PID

(2) *area*, x, z, $k_{p,6}$, $k_{i,6}$, $k_{d,6}$, $k_{p,2}$, $k_{i,2}$, $k_{d,2}$, $k_{p,1}$, $k_{i,1}$, $k_{d,1}$,

The parameters of the rudder

Area: area of the rudder;

x, z: position of the rudder;

$k_{p,6}$, $k_{i,6}$, $k_{d,6}$: PID parameter of yaw;

$k_{p,2}$, $k_{i,2}$, $k_{d,2}$: PID parameter of sway;

$k_{p,1}$, $k_{i,1}$, $k_{d,1}$: PID parameter of surge;

4.4.25. SECOND-ORDER-FORCE (*optional*)

Calculate the second-order forces by near-field integral of pressure, middle-field integral of pressure and far-field momentum.

(1) *Flag*

Flag: SECOND-ORDER-FORCE

(2) *near, middle, far*

Whether to exert: 0 - No; 1 - Yes

Near: 0 - No; 1 - Yes; 2 - only mean drift forces

(3) *pinkster, newman*

Whether to exert: 0, No; 1: Yes

4.4.26. IRREGULAR-FREQUENCY (*optional*)

Automatic to generate the mesh model of the internal free surface for eliminating the irregular frequency. **Caution**: in this case, the mesh on the internal free surface in the original file of wet grid model will be removed automatically.

(1) Flag

Flag: IRREGULAR-FREQUENCY

(2) *irregFreqFlag* xNum(maxArea) yNum(minAngle)

irregFreqFlag: 0 – no; 1 – mapping quadrilateral elements, *xNum yNum* ; 2 – free triangular element, *maxArea*, *minAngle*.

xNum: 20 (default)

yNum: 7 (default)

maxArea: 50 (default)

minAngle: 30 (default)

4.4.27. AUTO-FREE-CONTROL (*optional*)

Automatic to generate the mesh models of free and control surfaces for "IORM" method or middle- field method of second-order forces.

(1) *Flag*

Flag: AUTO-FREE-CONTROL;

(2) *freeControlFlag xNum(maxArea) yNum(minAngle)*

freeControlFlag : 0 – no; 1 – Yes.

geoControlType = 1 (default): 1 - Ellipsoid; 2 - Elliptic cylinder; 3 - Cube

geoControlA = 1.5*Lpp (default);

geoControlB = 0.8*Lpp (default);

geoControlC = 0.7*HEIGHT (default);

4.4.28. STABILITY-CORRECTION (*optional*)

The parameters are for modifying the internal metacentric heights of roll and pitch (GM_{xx} and GM_{yy}), which are added to not replaces the GM_{xx} and GM_{yy}.

(1) *Flag*

Flag: STABILITY-CORRECTION;

(2) *rollStabilityCorrection pitchStabilityCorrection*

The parameters are for modifying the internal metacentric heights of roll and pitch.

4.4.29. SECTION-LOAD-COEFFICIENTS (*optional*)

Function: the parameters are for the mode superposition of sectional wave loads of each section.

Notes: ***sagging - '-'***, ***hogging - '+'***; Especially be careful when generating load coefficients in mode superposition method.

(1) *Flag*

Flag: SECTION-LOAD-COEFFICIENTS;

(2) *secNum_modeSuperposition modalNumForSuperposition*

secNum_modeSuperposition: the number of load section. 0 – not only section, -1 – from single file

modalNumForSuperposition: the number of elastic modes for mode superposition, which *could be not equal to that in responses of principal coordinates*.

(3) if *modeSuperposition* = -1, it is the single file name of load coefficients.

if *modeSuperposition* >= 0,

Mode-n	*Fx*	*Fy*	*Fz*	*Tx*	*My*	*Mz*
Sec-m	*value1*	*value2*	*value3*	*value4*	*value5*	*value6*

4.4.30. FILTER-COMPONENTS (*optional*)

Function: filter the components of responses in time domain, such as motions and wave load. And the statistic value of maximum, minimum and amplitude of these responses will also be affected.

Option freqLow freqHigh

(1) *Option*

Option: FILTER-COMPONENTS; 0 – not filter, 1 – band pass, -1 – band stop.

(2) *freqLow*

freqLow: the lower limit of the filter, unit: Hz;

(3) *freqHigh*

freqHigh: the higher limit of the filter, unit: Hz;

4.4.31. Example

```
JOB WALAS
"ship1_nodeElement.wet"
"ship1_nodeElement.dry"
"ship1_node.modal"
"ship1_element.modal"
"ship1_element.dudx"
"ship1_nodeElement_free.wet"
"ship1_nodeElement_control.wet"
"ship1_wave.in"
"ship1_slmParam.ini"
30    0    2    1    1    1    1    -4    4.0    0.05
0    0    -1
98470    5.323E+06    5.758E+06    0    0    0
0    0    0    0
0    1025    9.81    1500
1    1000.0
1    42
0.1    0.2    0.3    0.4    0.5    0.6
0.7    0.8    0.9    1    1.1    1.2
1.3    1.4    1.5    1.6    1.7    1.8
1.9    2    2.1    2.2    2.3    2.4
2.5    2.6    2.7    2.8    2.9    3
3.1    3.2    3.3    3.4    3.5    3.6
3.7    3.8    3.9    4    4.1    4.2
1    5
```

0 45 90 135 180

200

0 0 6

0 1

0.10 0.10 0.03 0.03 0.03 0.10

0.01 0.01 0.01 0.01 0.01 0.01

40

1.390E+03 -1.425E+01 1.014E+00 -1.000E+00 0.000E+00

1.390E+03 -1.275E+01 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 -1.125E+01 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 -9.750E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 -8.250E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 -6.750E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 -5.250E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 -3.750E+00 1.014E+00 -1.000E+00 0.000E+00

3.390E+03 -2.250E+00 1.014E+00 -1.000E+00 0.000E+00

3.390E+03 -7.500E-01 1.014E+00 -1.000E+00 0.000E+00

3.390E+03 7.500E-01 1.014E+00 -1.000E+00 0.000E+00

3.390E+03 2.250E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 3.750E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 5.250E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 6.750E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 8.250E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 9.750E+00 1.014E+00 -1.000E+00 0.000E+00

2.390E+03 1.125E+01 1.014E+00 -1.000E+00 0.000E+00

1.390E+03 1.275E+01 1.014E+00 -1.000E+00 0.000E+00

1.390E+03 1.425E+01 1.014E+00 -1.000E+00 0.000E+00

1.390E+03 -1.425E+01 -1.014E+00 -1.000E+00 0.000E+00

1.390E+03	-1.275E+01	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	-1.125E+01	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	-9.750E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	-8.250E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	-6.750E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	-5.250E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	-3.750E+00	-1.014E+00	-1.000E+00	0.000E+00
3.390E+03	-2.250E+00	-1.014E+00	-1.000E+00	0.000E+00
3.390E+03	-7.500E-01	-1.014E+00	-1.000E+00	0.000E+00
3.390E+03	7.500E-01	-1.014E+00	-1.000E+00	0.000E+00
3.390E+03	2.250E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	3.750E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	5.250E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	6.750E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	8.250E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	9.750E+00	-1.014E+00	-1.000E+00	0.000E+00
2.390E+03	1.125E+01	-1.014E+00	-1.000E+00	0.000E+00
1.390E+03	1.275E+01	-1.014E+00	-1.000E+00	0.000E+00
1.390E+03	1.425E+01	-1.014E+00	-1.000E+00	0.000E+00

3 -1

-7.500E+00	0.000E+00	-1.000E+00	0
0.000E+00	0.000E+00	-1.000E+00	0
7.500E+00	0.000E+00	-1.000E+00	0

SPRING-MOORLINE

-1

5e+05	5e+06	0	0	0	1e+10

RUDDER-PID

0

100 -200.0 0 3 0.1 0.1 3 0.1 0.1 1 0.1 0.1

SECOND-ORDER-FORCE

1 1 1

0 0

IRREGULAR-FREQUENCY

0

AUTO-FREE-CONTROL

0 0

STABILITY-CORRECTION

0 0

FILTER-COMPONENTS

0 0.05 100

4.5. Wave parameters of time-domain calculation (shipX_wave.in)

4.5.1. Case number

caseNum: number of cases

4.5.2. Case name

Name of the case

4.5.3. Wave parameters

Wave type, wave height, wave period

Wave type: 0 – regular wave, 1 – Jonswap, 2 – PM

Wave height: significant wave height (H_s)

Wave period: T_p – Jonswap, T_z – PM

4.5.4. Time points

Get amplitude, maximum, minimum between start time and end time

Time interval, total time, start time, end time

3.14159 1256.64 942.478 1068.14

4.5.5. Initial conditions of each mode

N - Number of initial conditions

Displacement1 Velocity1

Displacement2 Velocity2

Displacement3 Velocity4

…

DisplacementN VelocityN

4.5.6. Example

```
3
"B001"
0    2              62.8319
3.14159     1256.64     942.478     1068.14
6
0            0
0            0
0            0
0            0
0            0
0            0
"B002"
0    2              50.2655
2.51327     1005.31     753.982     854.513
6
0            0
0            0
0            0
0            0
0            0
0            0
"B003"
```

0 2 41.8879

2.0944 837.758 628.319 712.094

6

0 0

0 0

0 0

0 0

0 0

0 0

4.6. Slamming pressure and areas (shipX_slmParam.ini)

This file is for calculating whipping response in time domain. The file is the calculation formula of slamming pressure. There is a default slamming pressure calculation formula (Stavovy & Chuang) in the program. If the file does not exist, the default calculation formula in the program will be used.

4.6.1. Formulas of slamming pressure

No: Number of discrete points of the formulas

Factor: factor of discrete points of the formulas, default – 2.0

xn *yn*: coordinates of *x* and *y* of the points

Example:

No *Factor*

x1 *y1*

x2 *y2*

x3 *y3*

…

xn *yn*

4.6.2. Definition of slamming areas

X1: from stern to x1, considering slamming

X2: from x2 to bow, considering slamming

No: the number of wet elements to output slamming pressure (the number of the following elements follows the principle of sequential numbering from 1, which is not the element number in node-element file and is the number of full model)

Point1: element #1

Point2: element #2

Point3: element #3

Example:

X1 x2

No

Point1

Point2

…

PointN

4.6.3. Example

3

1.0 20.

2.0 24.

3.0 50.

50 330

3

147

148

149

4.7. Modal informations of dry model in Patran/Nastran (ship.f06)

This file is the result file of MSC / NASTRAN calculation, and saves the node modal information of dry model.

4.8. Dry model in Patran/Nastran (ship_dry.bdf)

The file is saved from the finite element model, which saves the node and element information of dry structure panel. This file is used for OpenWALAS_PRE program and ship_ wet.bdf. The modal information of wet model is calculated from ship.f06.

For convenience, it can be directly copied from the. BDF file of ship.f06, or re-extracted from the finite element model of the dry structure (only the elements on the surface of the floating body should be kept, and the number must be kept unchanged). The. BDF file corresponding to ship.f06 saves all the nodes of the modal calculation.

4.9. Wet model in Patran/Nastran (ship_wet.bdf)

The file saves the node and element information of wet surface element. Because the dimension of dry structure surface element is smaller than that of wet surface element, it is necessary to make wet surface element file again, but the surface element model of both can be maintained.

5. Instructions of Output files

5.1. Hydrodynamic coefficients in frequency domain (binary format)

case.hyd, including wave exciting forces, added mass, added damping, hydrostatic restoring matrix.

5.2. Hydrodynamic coefficients in time domain (binary format)

impulse.hyd, inducing the impulse response functions of incident wave exciting forces (Fkr), diffraction exciting forces (Fdr) and radiation potential (Krs).

5.3. Results in frequency domain (text format)

(1) case.LIS, including overall basic information

(2) ship1.LIS, basic information and results for each floating structures.

5.4. Results in time domain (text format)

(1) ship1_TIM.LIS, basic information in time domain.

(2) ship1_t2f.LIS, results of transfer function by time-domain programs.

5.5. 3D models of wet model

(1) *XX_ internal_nodeElement.plt*: Tecplot format, the elements above still water are removed.

(2) *nodeElement_coupledModels.plt*: Tecplot format, the coupled models.

(3) *nodeElement_allShips.plt*: Tecplot format, including all models.

(4) *integral_model.DXF*, *XX_ original_nodeElement.DXF*: Autocad format, full model, the elements above still water are reserved.

6. Examples

6.1. Create a new project

See Section 3.3.

6.2. Single floating structure

File directory: example/Bulk carrier (20,500 tons), example/Canada Frigate97, example/container ship (6,750 TEU), example/container ship (20,000 TEU), example/s175 and example/wigley.

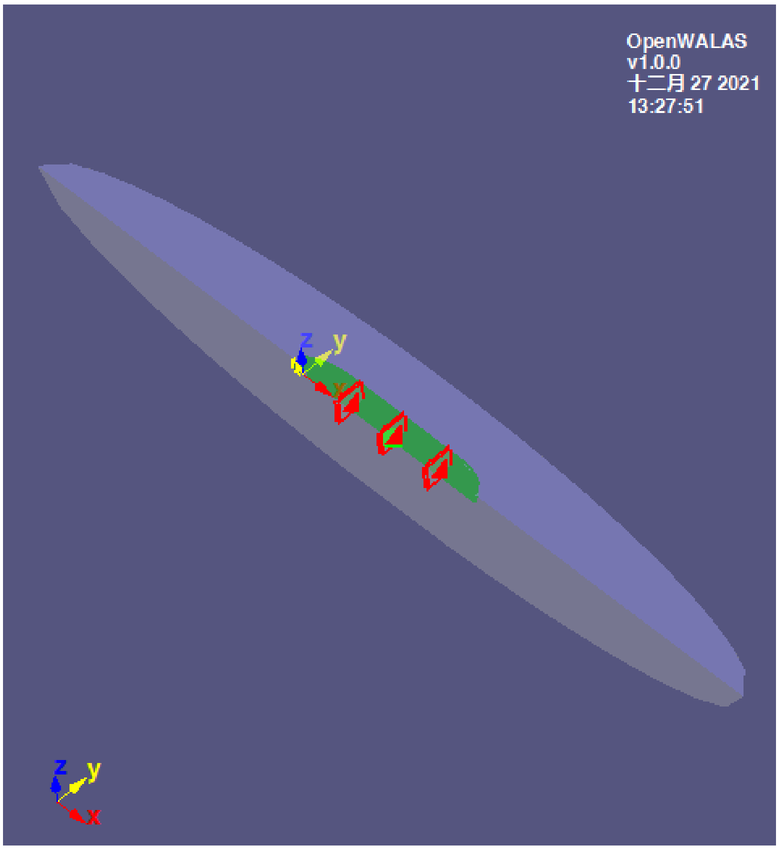


Fig. 55 A bulk carrier (20,500 tons)

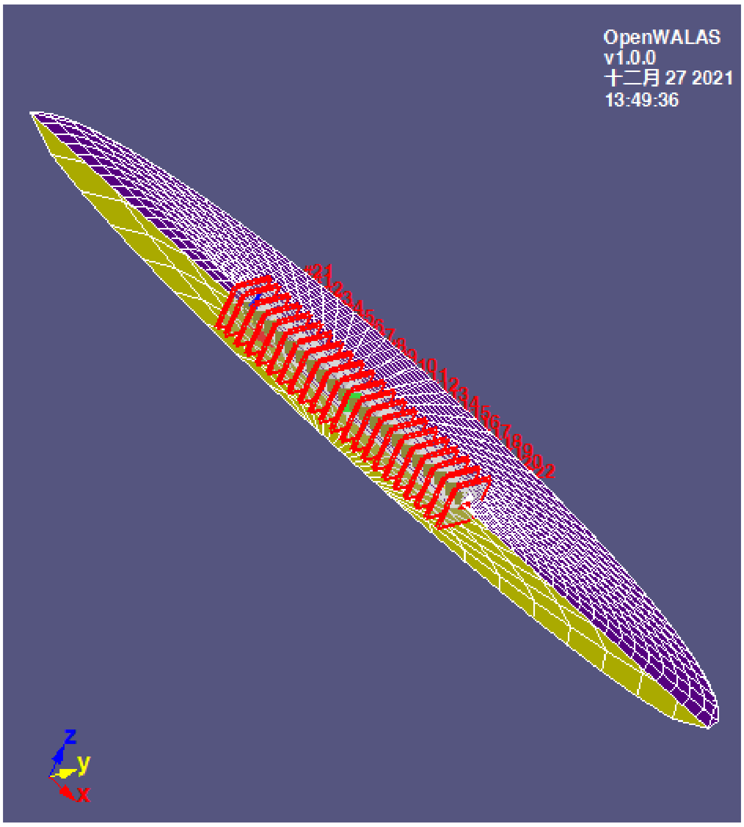


Fig. 56 A Canada frigate

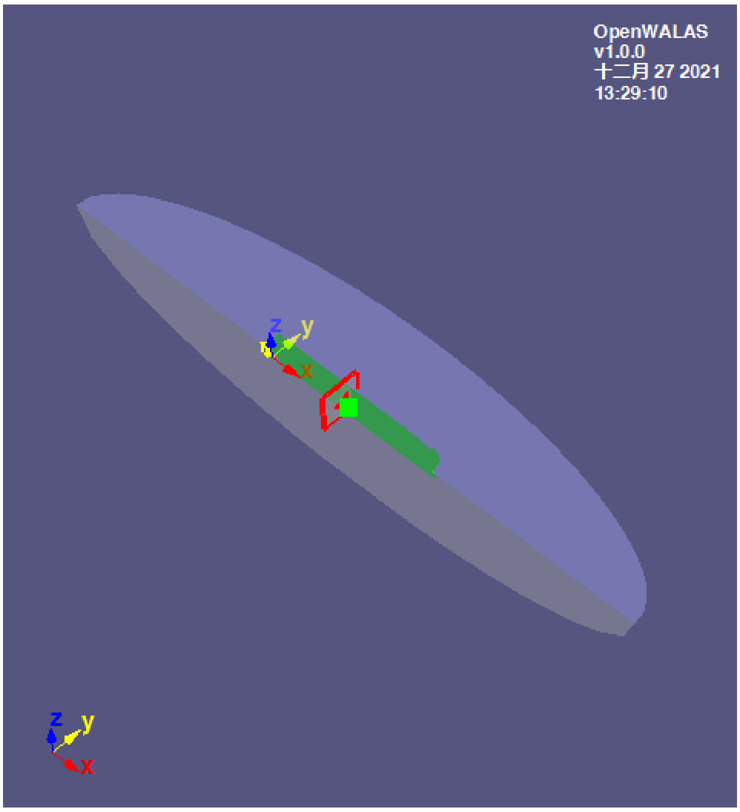


Fig. 57 A container ship (6,750 TEU)

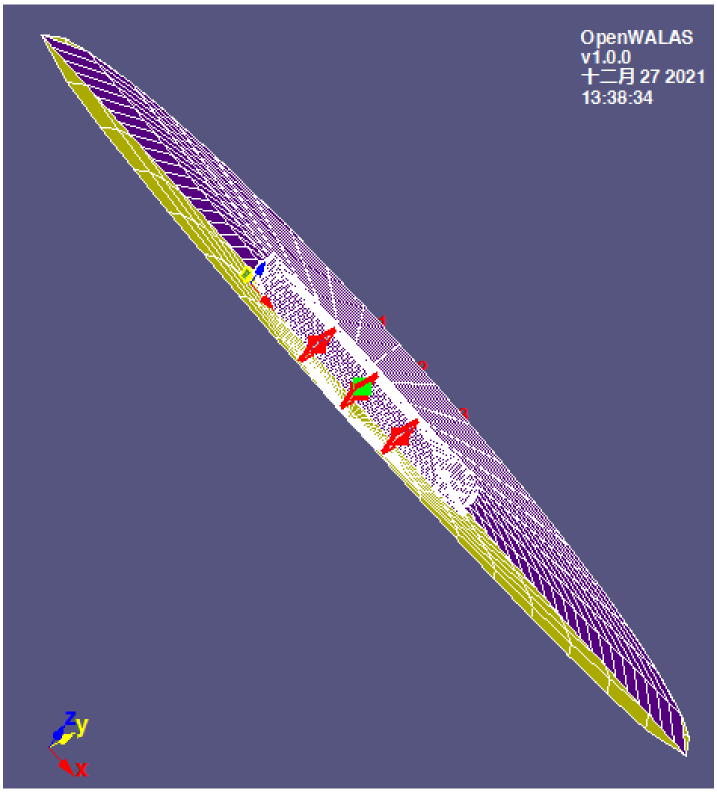


Fig. 58 A container ship (20000 TEU)

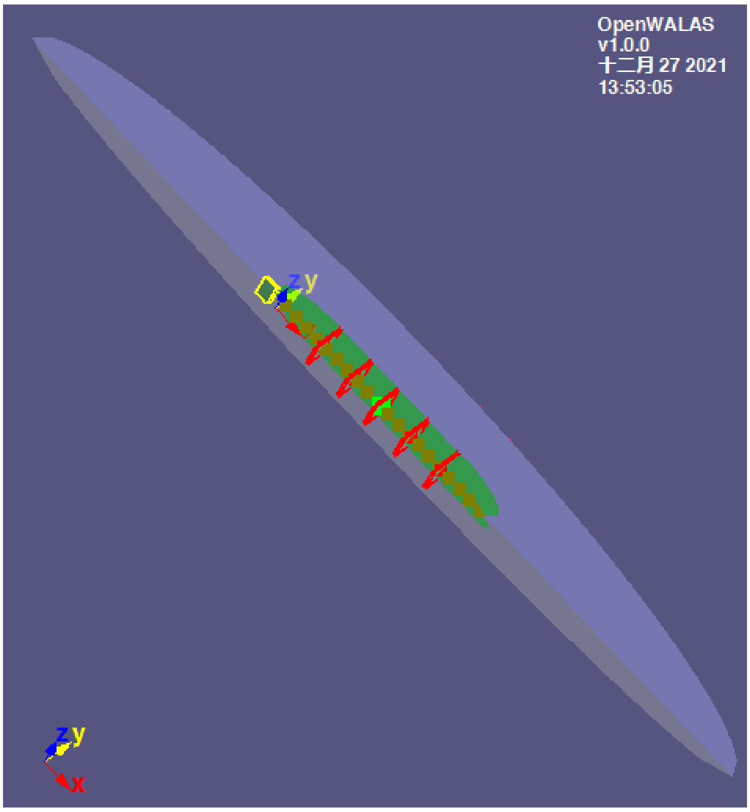


Fig. 59 S-175 container ship

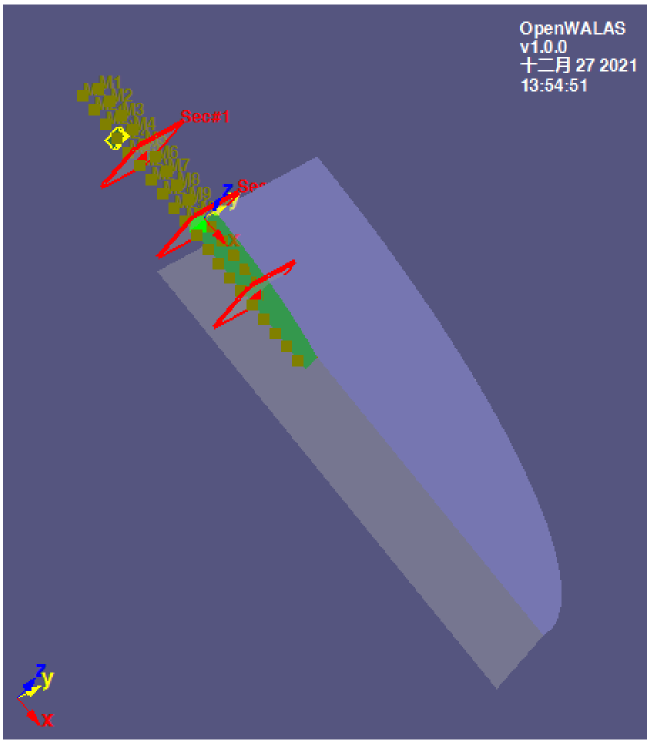


Fig. 60 Wigley ship

6.3. Multi-floating structures

File directory: example/cylinder_barge

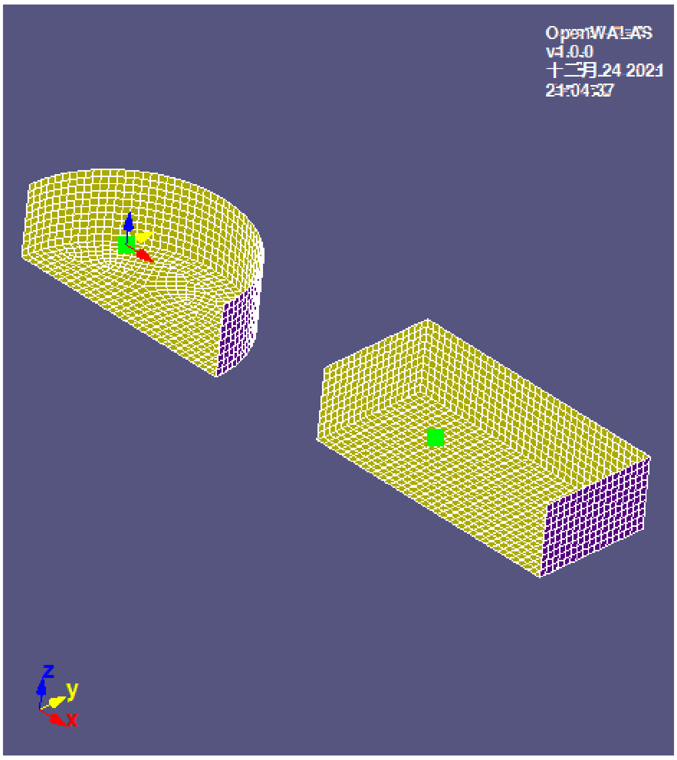


Fig. 61 Multi floating structures

7. Other useful tools

The interface between OpenWALAS and Patran or ANSYS are built by the tools as follows, which are in directory of “tools” in OpenWALAS.

1. *createElem(ansys)* – create mesh model in AYSYS from files of nodeElement.dat.
2. *createhull(ansys)* – create hull model in AYSYS from lines of ship hull.
3. *createElem(patran)* – create mesh model in PATRAN from files of nodeElement.dat.
4. *createhull(patran)* – create hull model in PATRAN from lines of ship hull.
5. *getModal(ansys)* – get modes of structural elastic vibration shapes from ANAYS.
6. *getNodeElement(ansys)* – get mesh model of ships from ANAYS.
7. *bdf2walas* – transfer grid model form .bdf file of Patran to OpenWALAS.
8. *aqwa2walas* – transfer input file of aqwa to the input file of OpenWALAS.
9. *shorterm* - response prediction in short-term sea states.

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