



# Three-dimensional Analysis Software of Wave Loads and Hydroelasticity User Manual



## OpenWALAS (Open Wave Load Analysis Software)



**Author:** *Peng Yang*

**Email:** *pycssrc@qq.com*

**Date:** *May 19<sup>th</sup>, 2021*



## ◆ Copyright

*OpenWALAS* is distributed under the terms of the [GNU General Public License](#) (GPL).

(a) Some answers to common questions about the license:

◦ *If I write an application which uses OpenWALAS, am I forced to distribute that application?* No. The license gives you the option to distribute your application if you want to. You do not have to exercise this option in the license.

◦ *If I wanted to distribute an application which uses OpenWALAS, what license would I need to use?* The GNU General Public License (GPL).

(b) The bottom line for commercial users:

◦ *OpenWALAS can be used internally (‘in-house’) without restriction, but only redistributed in other software that is under the GNU GPL.*

The author always respects the intellectual property rights and labor achievements, and supports the behavior of sharing software and related documents. Any organization and individual can freely share the program and related documents within a limited scope, but the following principles should be followed.

(a) The projects encourage relevant researchers and authors to carry out joint-research, utilize this program, and further improve the program, so as to contribute to the technology development of global ship and ocean engineering;

(b) Copyrights of the software and documents belongs to the original author;

(c) This program shall not be used for any commercial purpose without the permission of the original author, otherwise it will be deemed as infringement;

(d) The source and the original author must be cited, if the software and the contents of this document are reprinted;

(e) For those who do not abide by this statement or illegally use this software and the contents of this document, the rights are reserved according to law.



作者一贯尊重知识产权和劳动成果，并支持分享软件和相关文档的行为，任何组织和个人在有限范围内可自由分享本程序和相关文档，但需遵循以下原则：

- 1、鼓励相关科研人员与作者开展联合研究，发挥本程序作用，并进一步完善程序，为全球船舶与海洋工程技术发展做贡献；
- 2、程序和文档的版权归原作者所有；
- 3、未经原作者允许不得将本程序用于**任何商业目的**，否则将视为侵权；
- 4、转载或者引用本程序和本文内容请**注明来源及原作者**；
- 5、对于不遵守此声明或者其他违法使用本程序和本文内容者，本人依法保留追究权等。



## Context

1. Software instruction .....	- 1 -
1.1. Basic information.....	- 1 -
1.2. Compiling and development environments .....	- 3 -
1.3. Installation and running environments.....	- 3 -
2. Theoretical fundamental .....	- 5 -
2.1. Coordinate systems .....	- 5 -
2.2 Wave direction and expression .....	- 6 -
3. Introduction of OpenWALAS GUI.....	- 8 -
3.1. Main GUI.....	- 8 -
3.2. Pre-process.....	- 22 -
3.3. Input parameters.....	- 30 -
3.4. Solution.....	- 40 -
3.5. Post-process and show results.....	- 41 -
3.6. Basic definitions.....	- 43 -
4. Introduction of OpenWALAS non-GUI.....	- 44 -
4.1. Running sequences.....	- 44 -
4.2. Main input file of different cases (case.ini) .....	- 44 -
4.3. Input parameters of floating structures (shipX.in).....	- 46 -
4.4. Wave parameters of time-domain calculation (shipX_wave.in).....	- 53 -
4.5. Slamming pressure and areas (shipX_slmParam.ini) .....	- 55 -
4.6. Modal informations of dry model in Patran/Nastran (ship.f06) .....	- 57 -
4.7. Dry model in Patran/Nastran (ship_dry.bdf).....	- 57 -
4.8. Wet model in Patran/Nastran (ship_wet.bdf) .....	- 57 -
5. Output instructions.....	- 58 -
5.1. Hydrodynamic coefficients in frequency domain (binary format) .....	- 58 -
5.2. Hydrodynamic coefficients in time domain (binary format) .....	- 58 -
5.3. Results in frequency domain (text format) .....	- 58 -



---

5.4. Results in time domain (text format) .....	- 58 -
5.5. 3D models of wet model .....	- 58 -
6. Other useful tools .....	- 59 -
References .....	- 59 -



# 1. Software instruction

## 1.1. Basic information

### 1.1.1. Introduction

OpenWALAS (*Open Wave Load Analysis Software*) is a suit of fluid-structural interaction software aiming to numerically calculate the motions, wave loads and hydroelastic responses of marine structures in waves, which is based on three-dimensional potential theory and mode superposition principle of elastic structures. And the velocity and pressure are respectively solved by 3D boundary element method 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 in frequency domain.

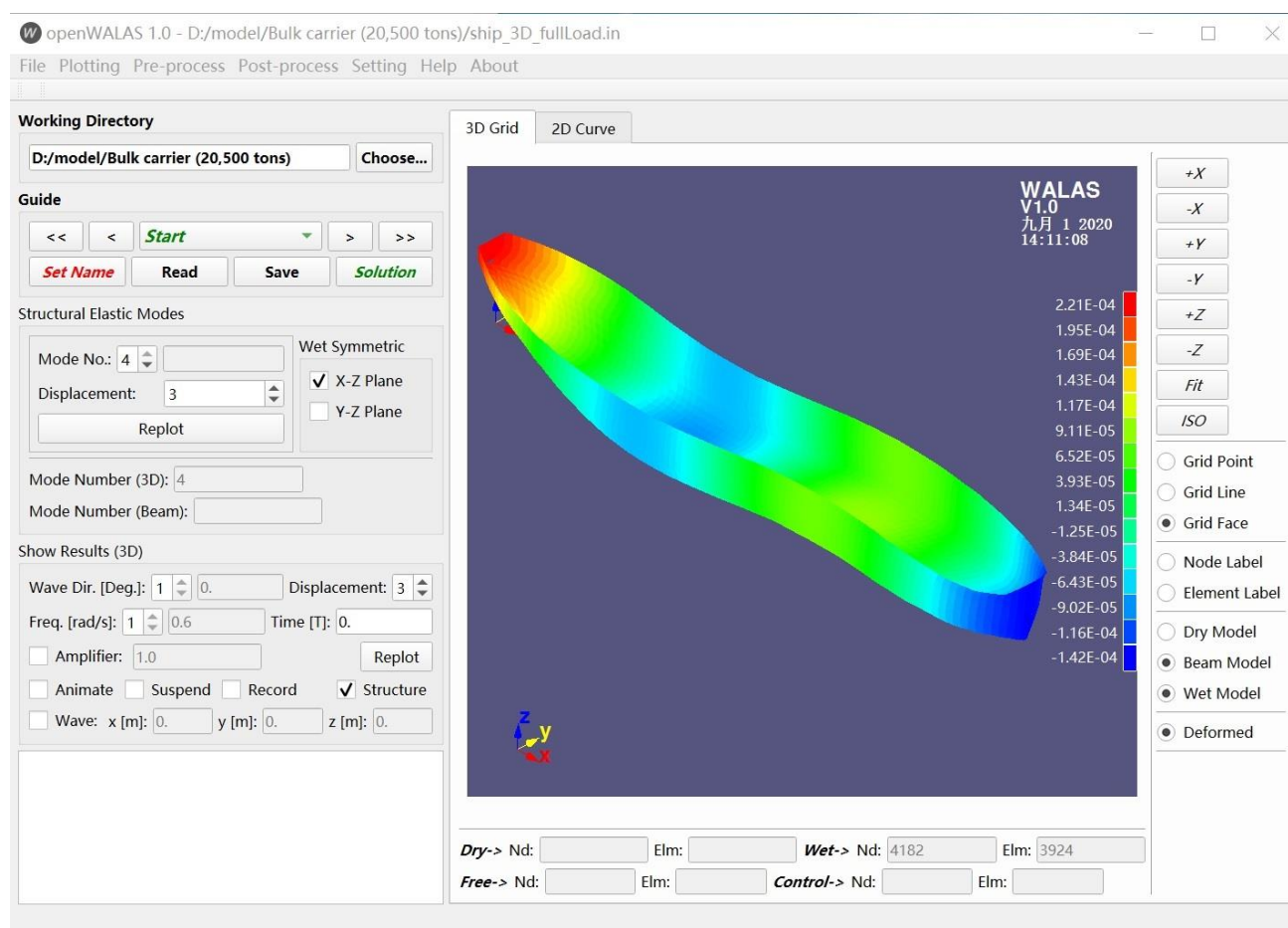


Fig. 1 OpenWALAS GUI



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 (or opensource) software to scientists and engineers all over the world.

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.

- OpenWALAS\_PRE program for pre-processing, is mainly used to calculate the mode of wetted floating structures from dry modal informations, 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 potential, impulse response function of diffraction potential, impulse response function of incident potential, impulse response function of 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) 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, as well as motions and wave loads, hydroelastic modal responses, wetted surface pressure, and wave height distribution of surrounding flow field 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.
- 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, 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) - 7.3.0; 3. gsl-2.6; 4. Qwt-6.1.4; 5. Opencv-4.2.0.

## 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. 2, 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. 2 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  $\Gamma$ , infinite boundary  $S_\infty$ .  $\Omega$  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.

$$\begin{cases} x_0 = x + U_0 t, y_0 = y, z_0 = z, \nabla_{x_0} = \nabla_x \\ \frac{\partial}{\partial t} \Big|_{x_0} \rightarrow \frac{\partial}{\partial t} \Big|_x - U_0 \frac{\partial}{\partial x} \Big|_x \end{cases} \quad (1)$$

## 2.2 Wave direction and expression

The definition of wave direction  $\beta$  shown in Fig. 3, 0 degree and 180 degree denote following sea and heading sea, respectively.

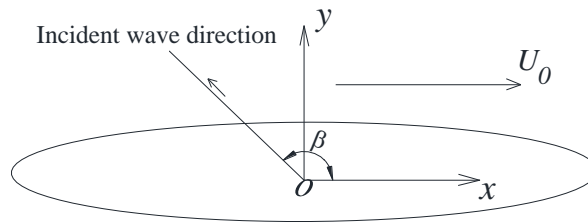


Fig. 3 Sketch of wave direction

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

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



where the variables  $A$ ,  $k$  and  $\omega$  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  $\Phi_1$  in the equilibrium coordinate system is

$$\Phi_1 = \text{Re} \left[ \phi_1 e^{-i\omega t} \right] = \text{Re} \left[ \frac{Ag}{i\omega} \frac{\cosh k(z+h)}{\cosh kh} e^{ik(x \cos \beta + y \sin \beta) - i\omega t} \right] \quad (3)$$

where  $\phi_1$ ,  $h$  and  $g$  denote the amplitude of the incoming potential of fluid, the water depth and the gravitational acceleration constant, respectively.



## 3. Introduction of OpenWALAS GUI

### 3.1. Main GUI

#### 3.1.1. New Project (case.in)

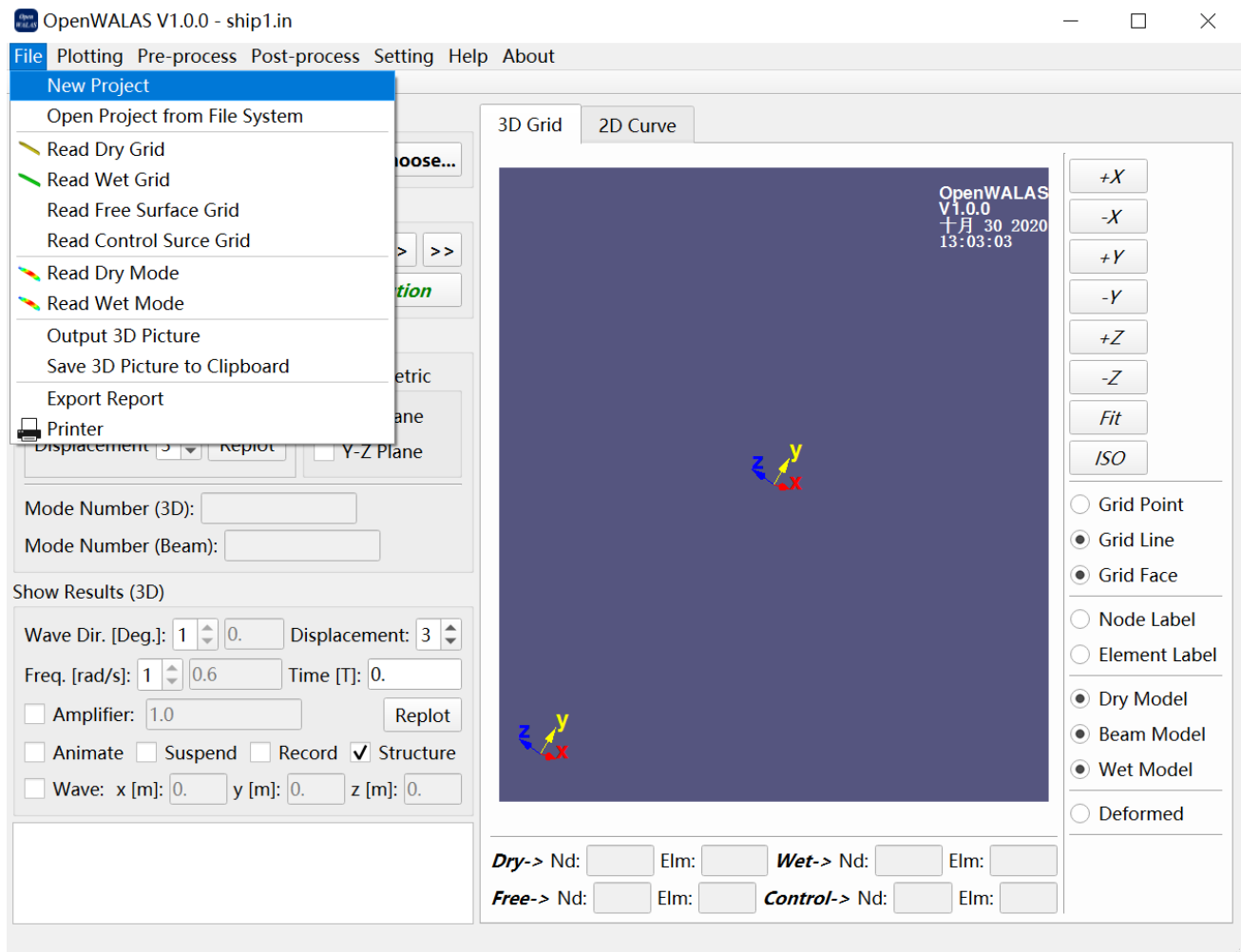
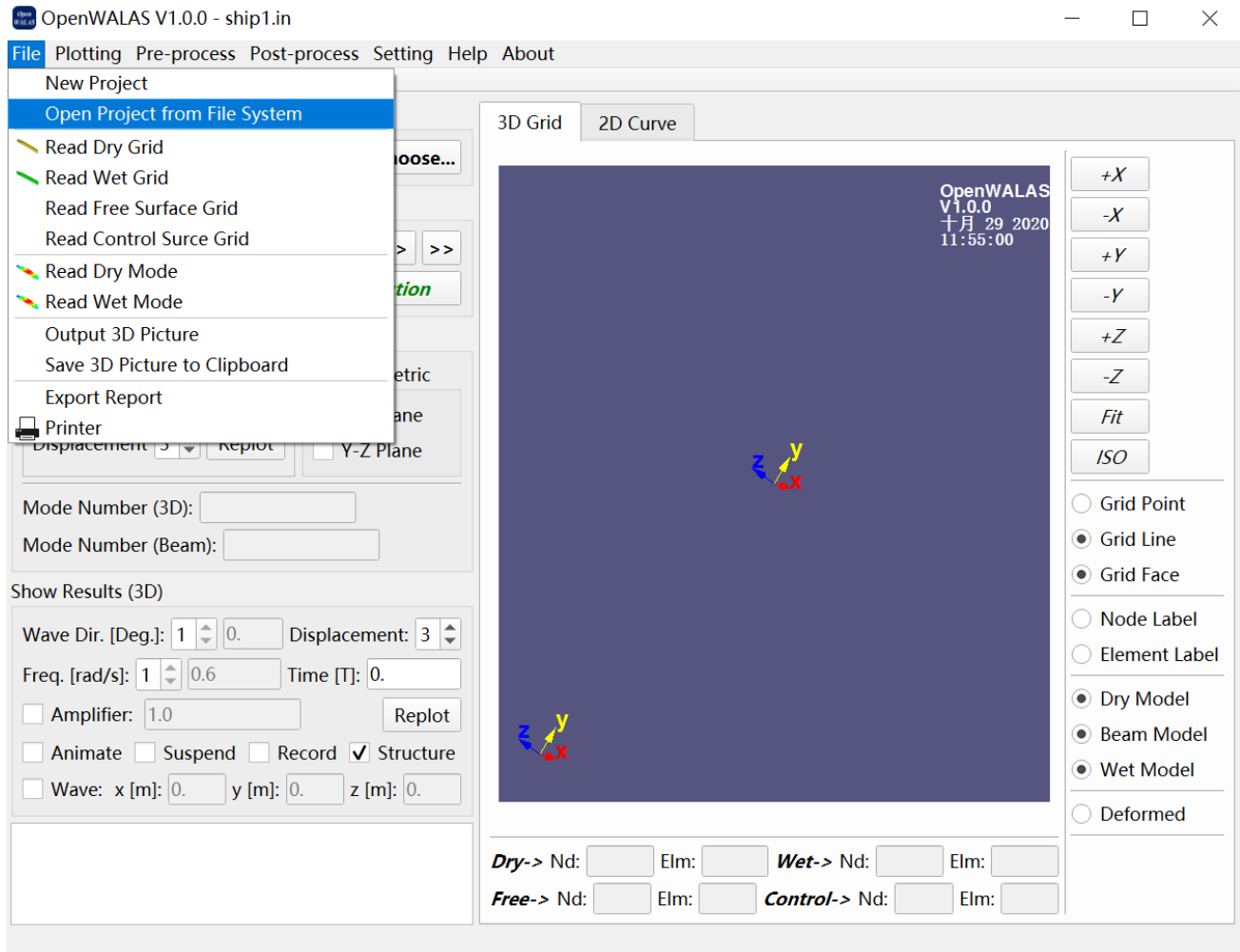




Fig. 4 New configuration file of new project



### 3.1.2. Open Project (case.ini)



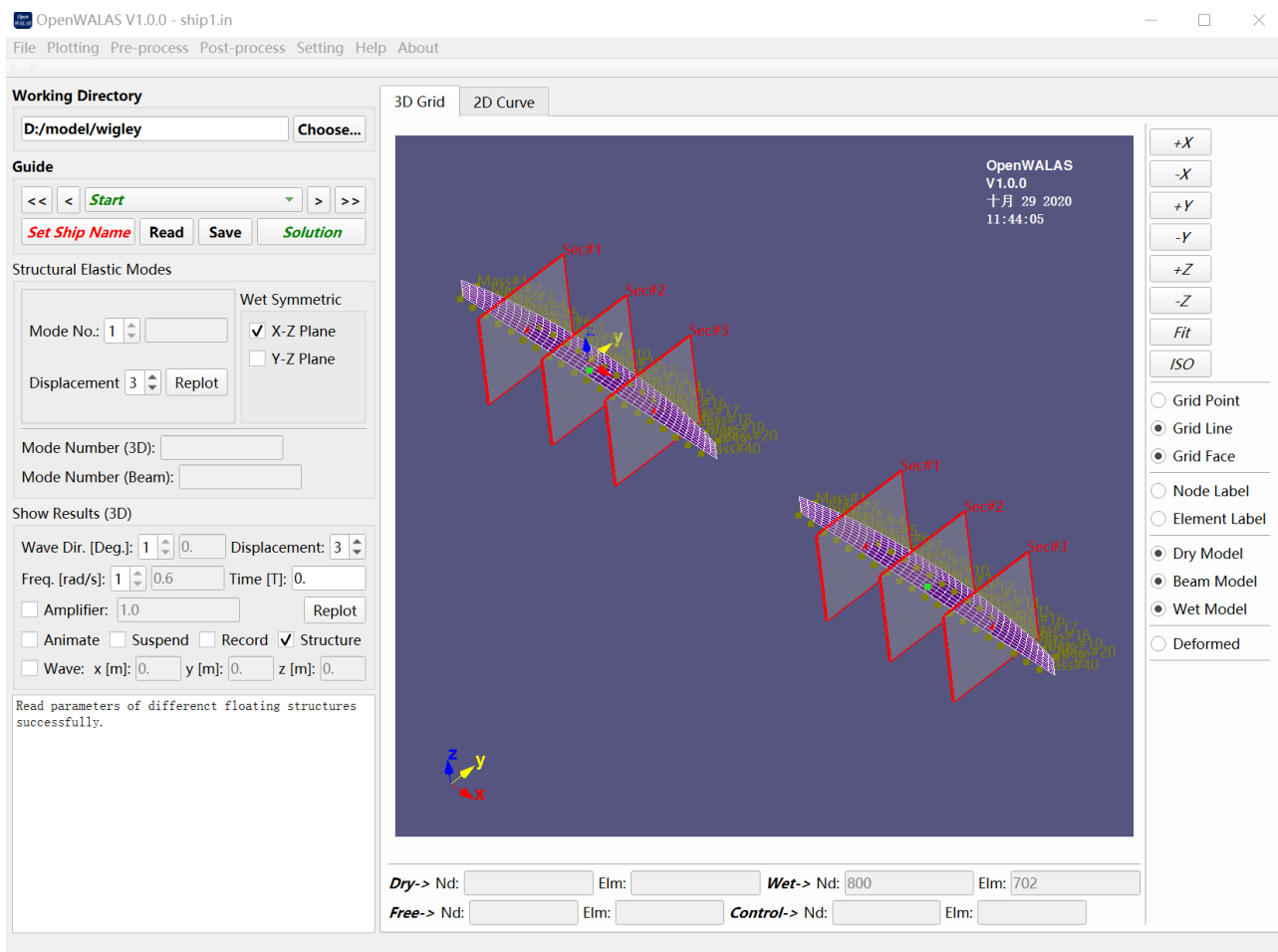


Fig. 5 Multi floating structures





### 3.1.3. Set working directory

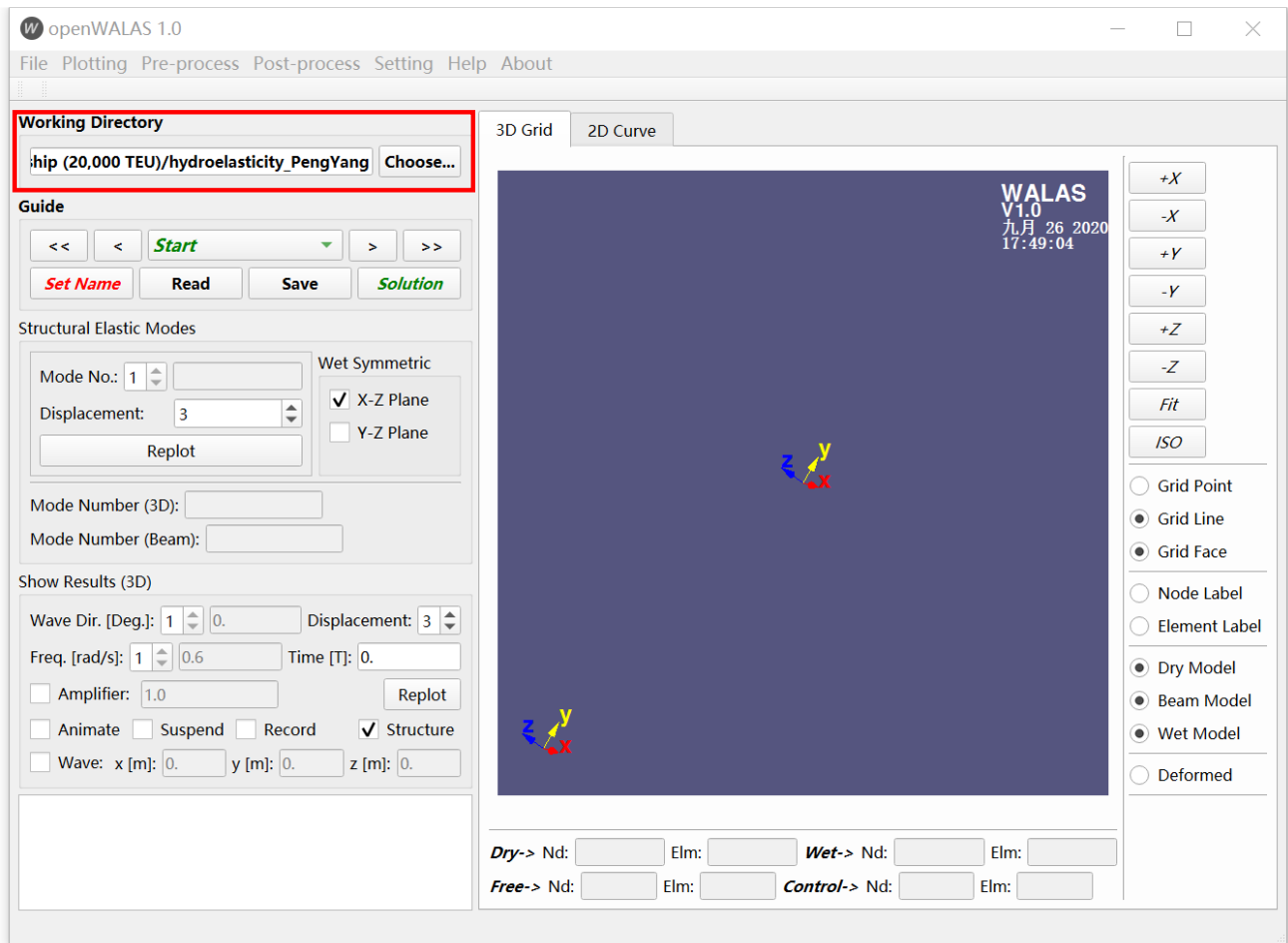


Fig. 6 Working directory



### 3.1.4. Set a file name of floating structure



Fig. 7 Set file name



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



Fig. 8 One floating structure



### 3.1.6. Show dry model

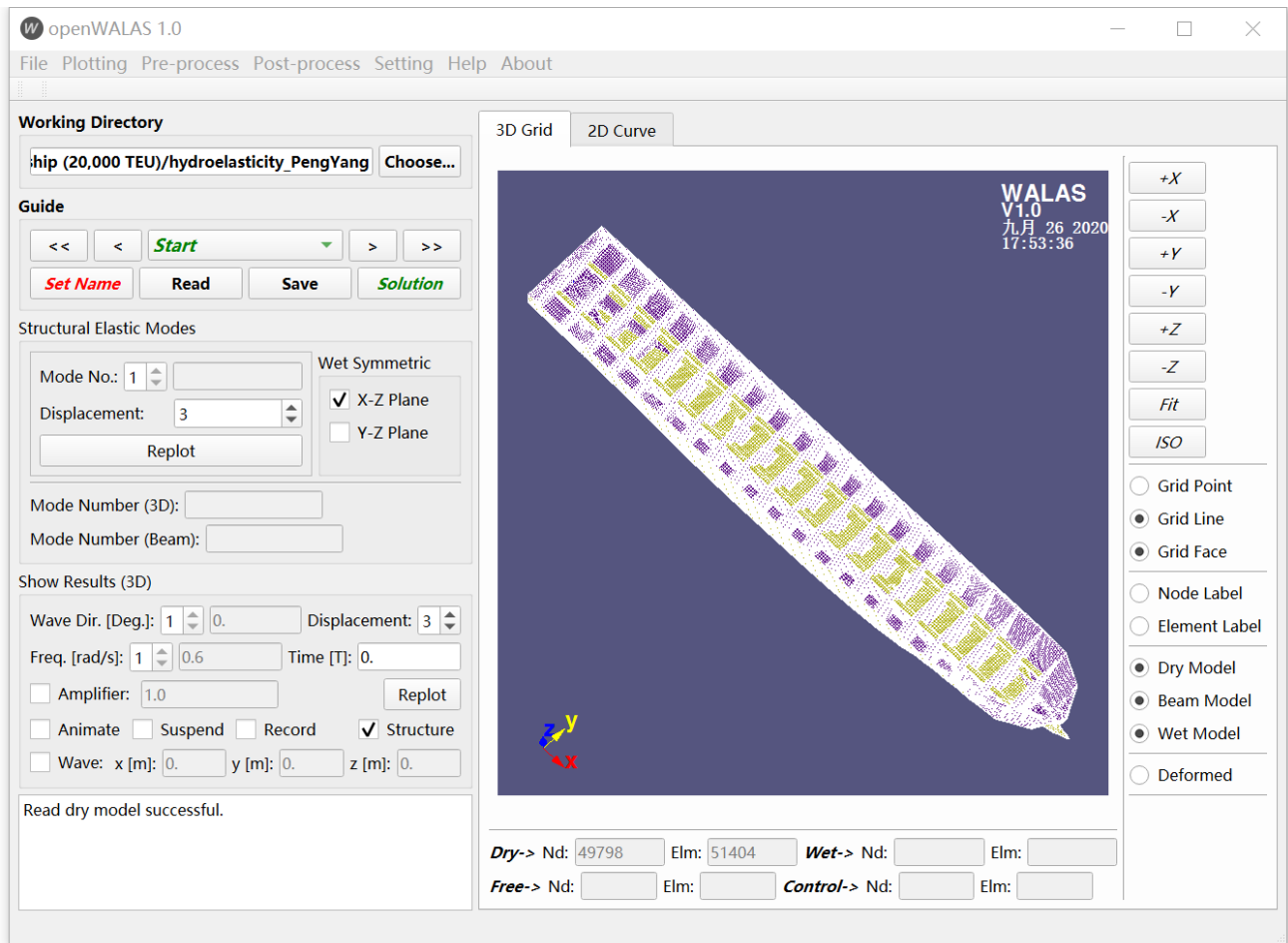


Fig. 9 3D FEM model

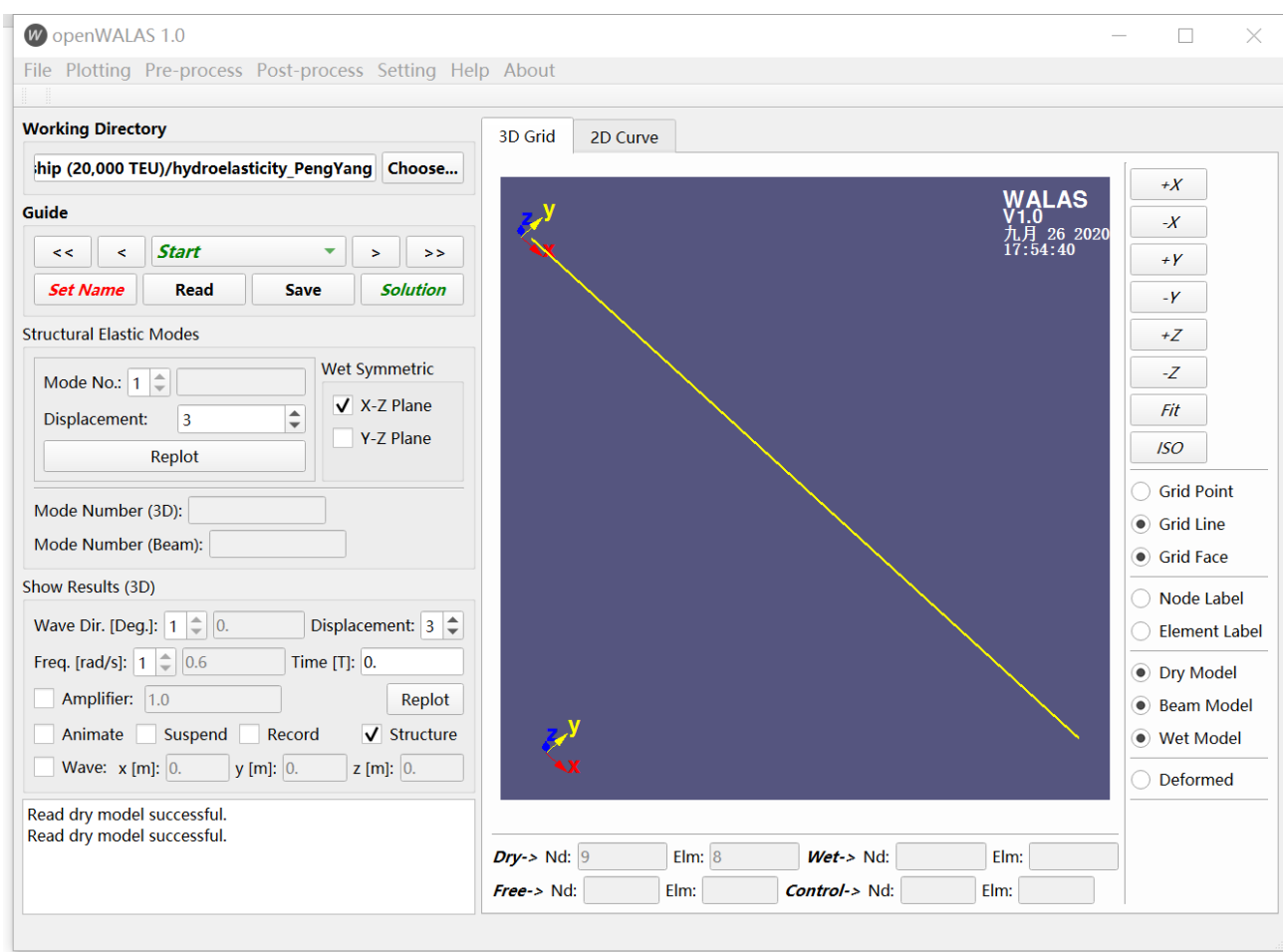


Fig. 10 1D beam model



### 3.1.7. Show wet model

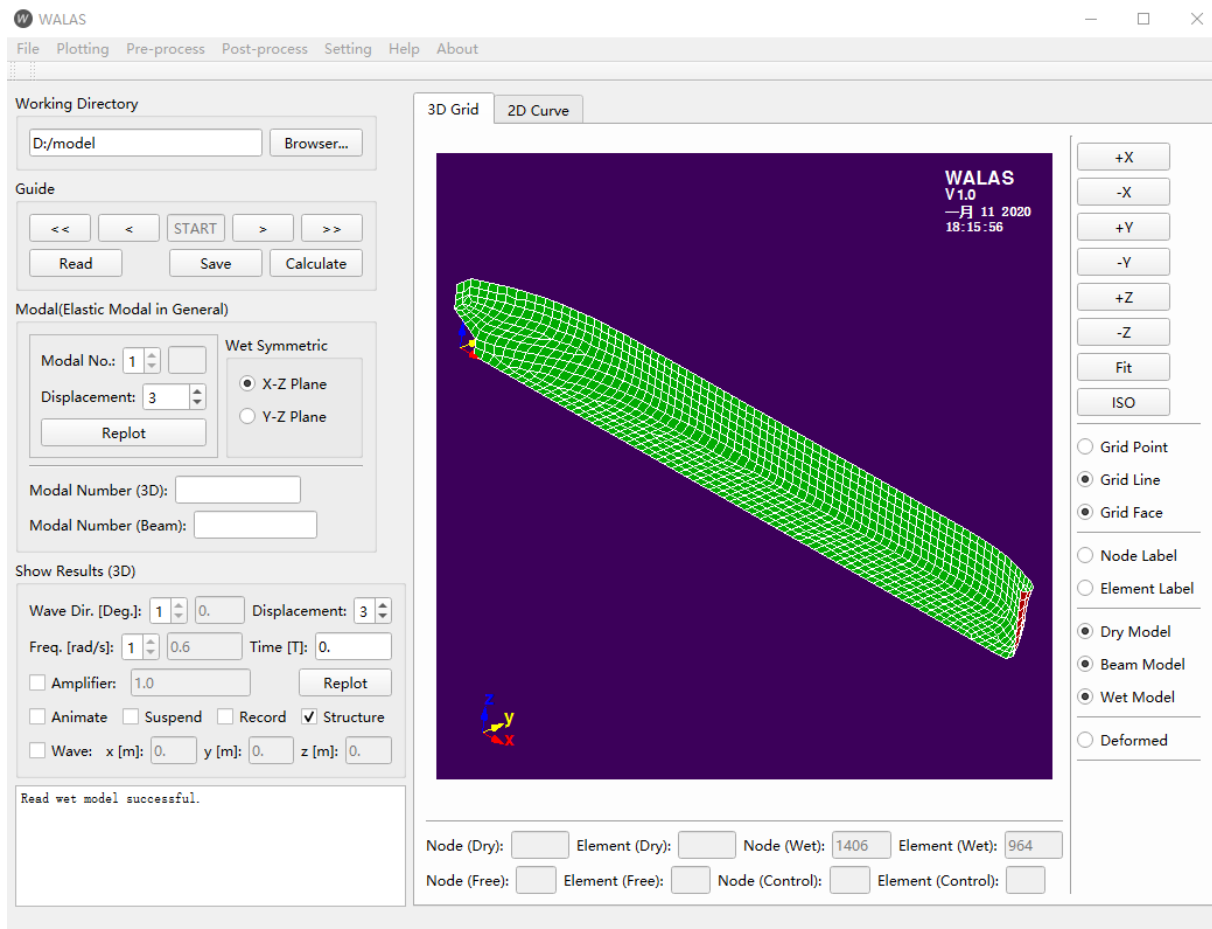


Fig. 11 3D wet model



### 3.1.8. Show free surface model

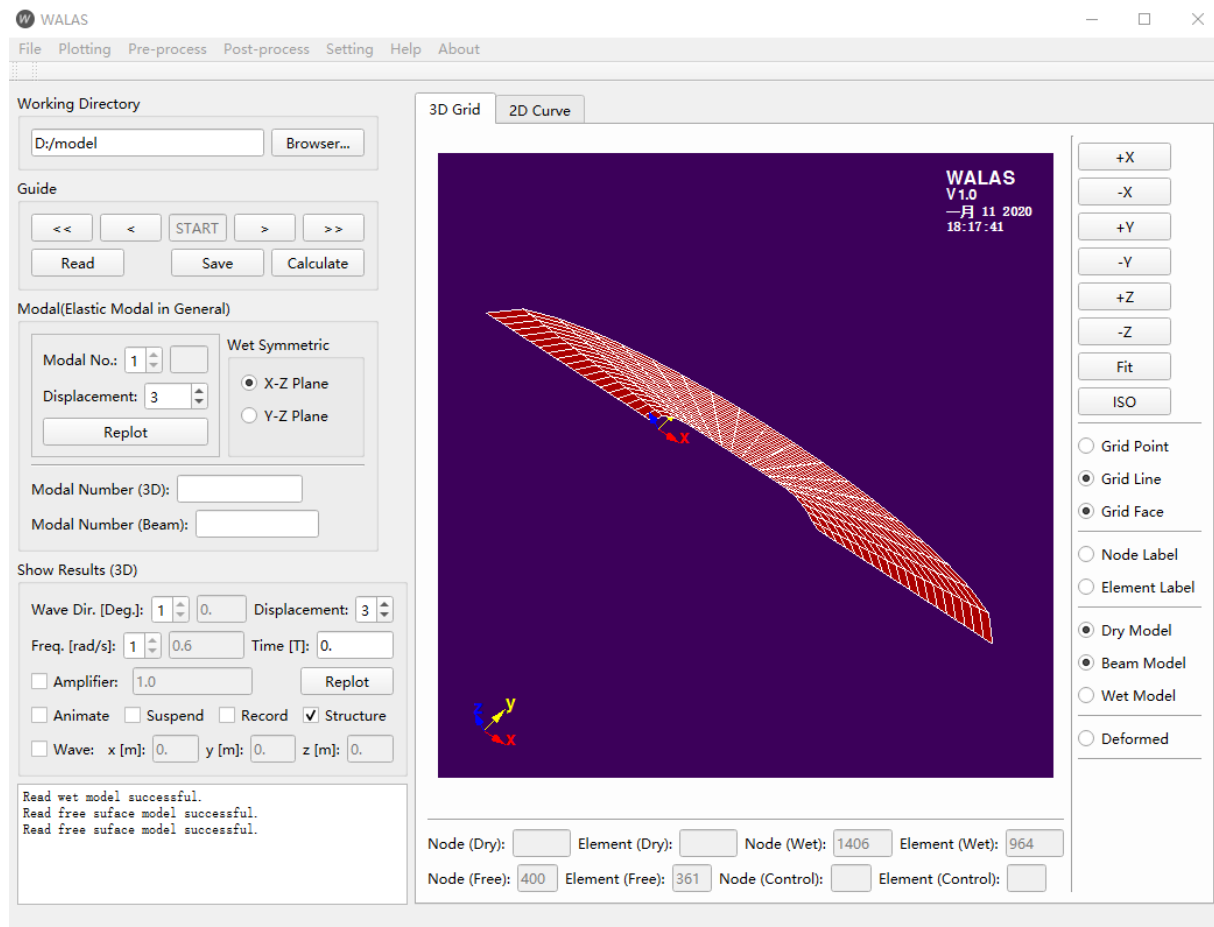


Fig. 12 Meshes on free surface



### 3.1.9. Show control surface model

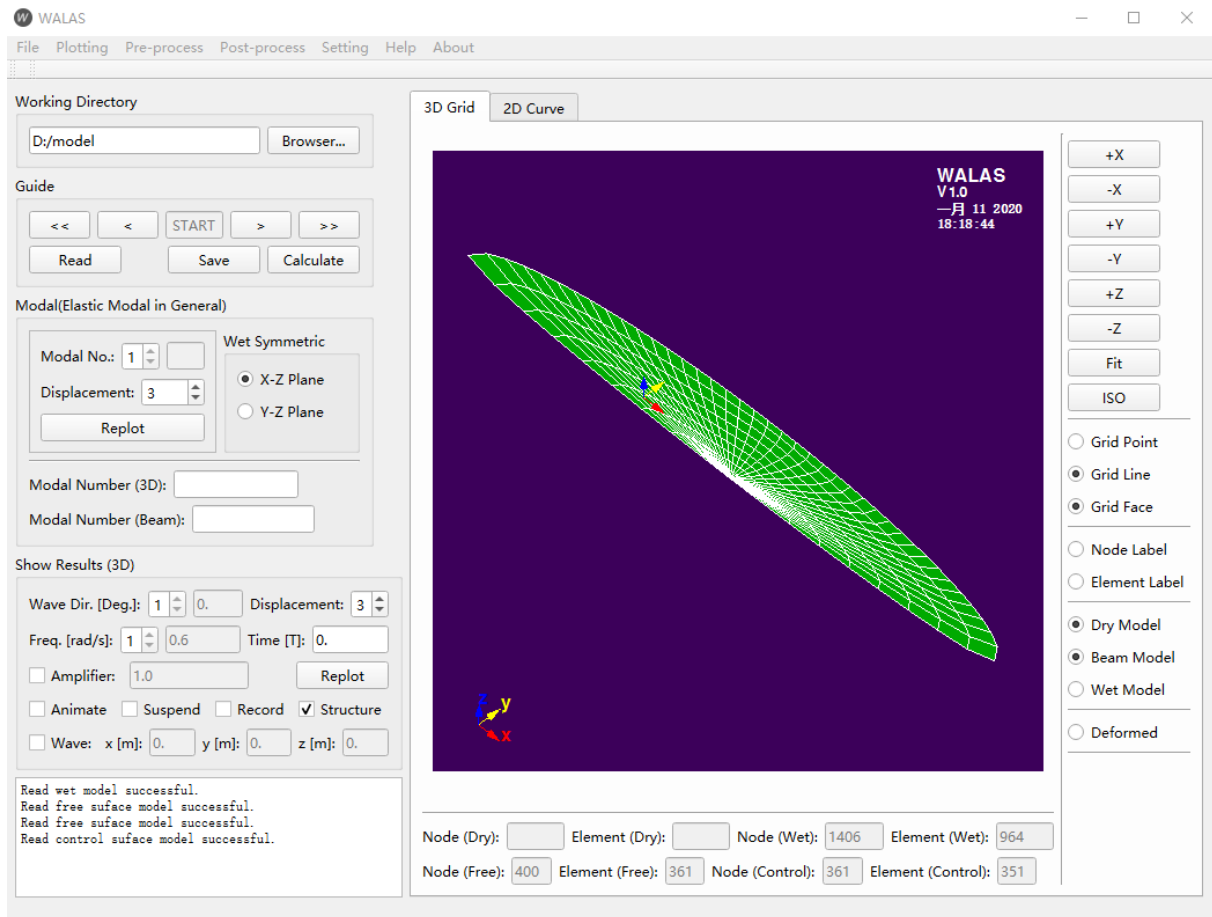


Fig. 13 Meshes on control surface





### 3.1.10. Show modes of dry models

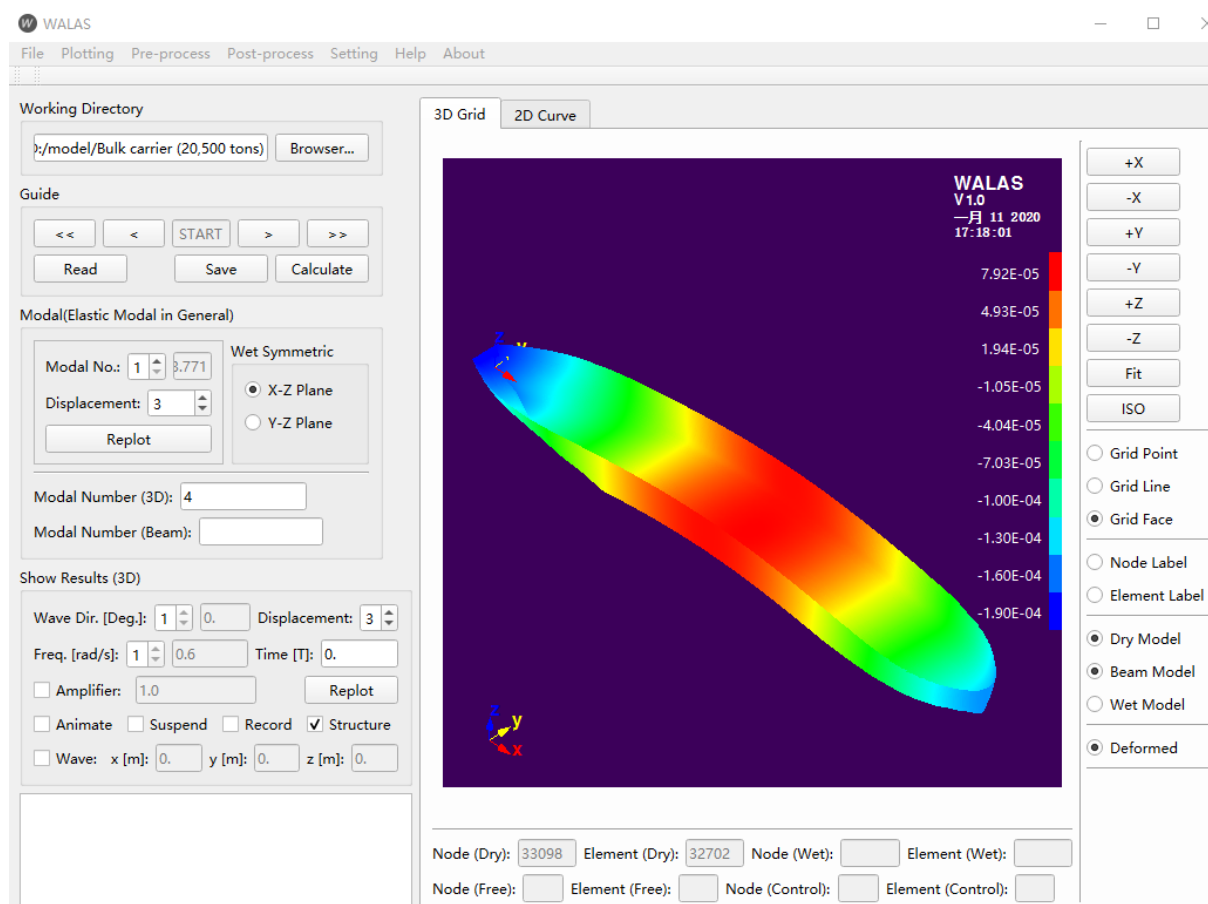


Fig. 14 3D FEM model

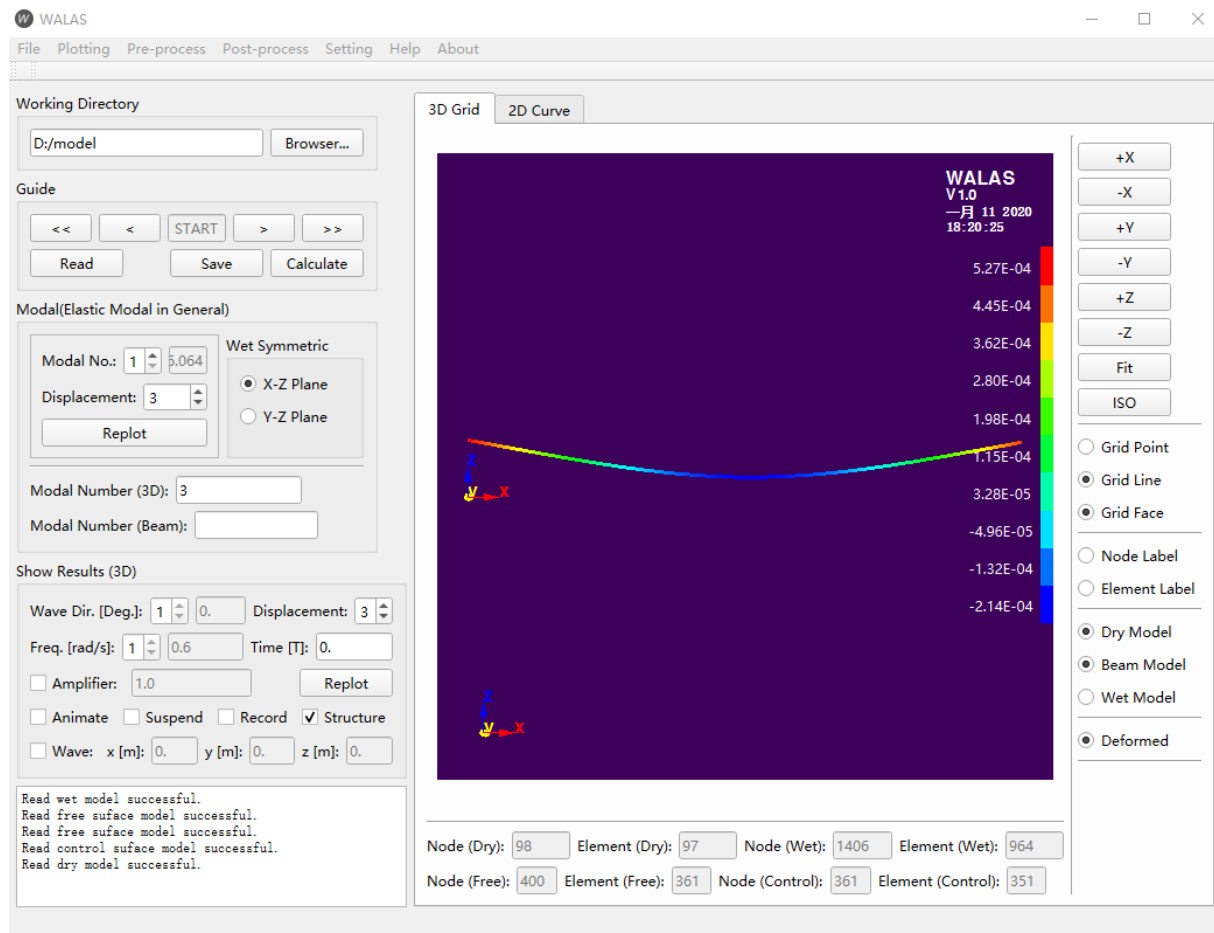


Fig. 15 1D beam model



### 3.1.11. Show modes of wet models

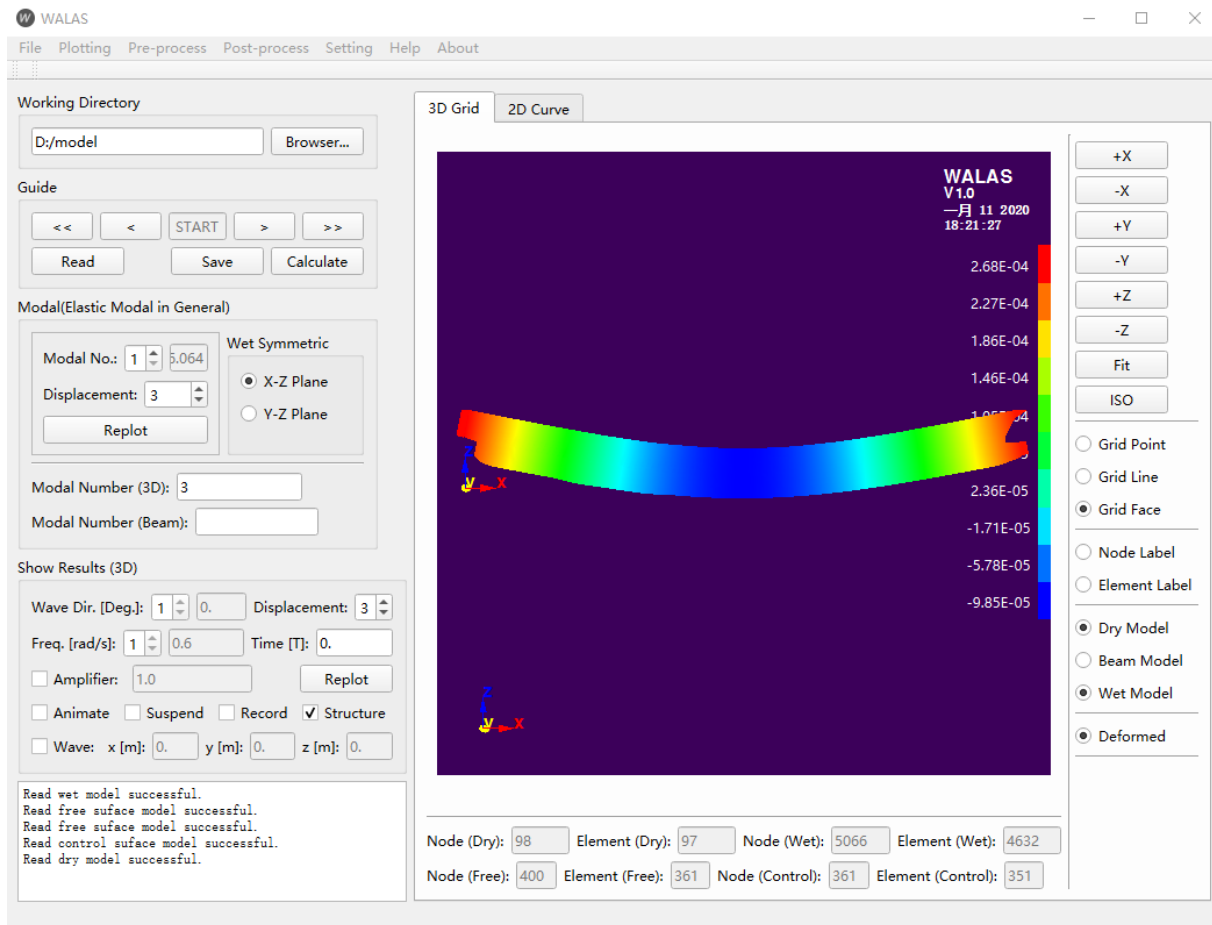


Fig. 16 3D wet model

## 3.2. Pre-process

### 3.2.1. Grid meshing

#### (1) Automatic meshing on ship hull



Fig. 17 Meshing on ship hulls

The format of file “hull.dat”:

*roll pitch*

*partNum, spline\_type, zWL, slice\_flag, delFlag*

*xn1 yn1*

*lineNum*

*pointNum*

*plx ply plz*

*...*

*pnx pny pnz*

*s*

**Explanation:**

*roll pitch*: roll and pitch about gravity center

*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
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**



W Automatically Generate Mesh

Hull Grid   Grid on Control and Free Surface   Grid on Internal Free Surface (Remove Irregular Frequency)

Parameters of Virtual Control Surface and Free Surface

Mesh Model Symmetric: ☐ 1/4   ☒ 1/2   ☐ Full

Control Surface Type: ☒ Sphere or Ellipsoid   ☐ Cylinder   ☐ Square

Slice Number(Control Surface): x Slice: 100   y Slice: 100

Mesh Type: 1: linear

Specified Middle Point of Water Line: 1

Control and Free Surface Size: a [m]: 400   a1 [m]: 400   b [m]: 100   b1 [m]: 100   c [m]: 50   x [m]: 150

Control Surface Element Size: xNum: 40   yNum: 20   zNum: 10

Free Surface Element Size: xNum1: 100   xNum2: 20   xNum3: 20   yNum: 20

Notes: Only for 'Square', variables a1 and b1 have effects. a1 can be different to a, and b1 can be different to b.

Read Parameters   Save and Generate   Mesh Control Surface   Mesh Free Surface

Fig. 18 Meshing on free surface and control surface

### (3) Meshing on internal free surface

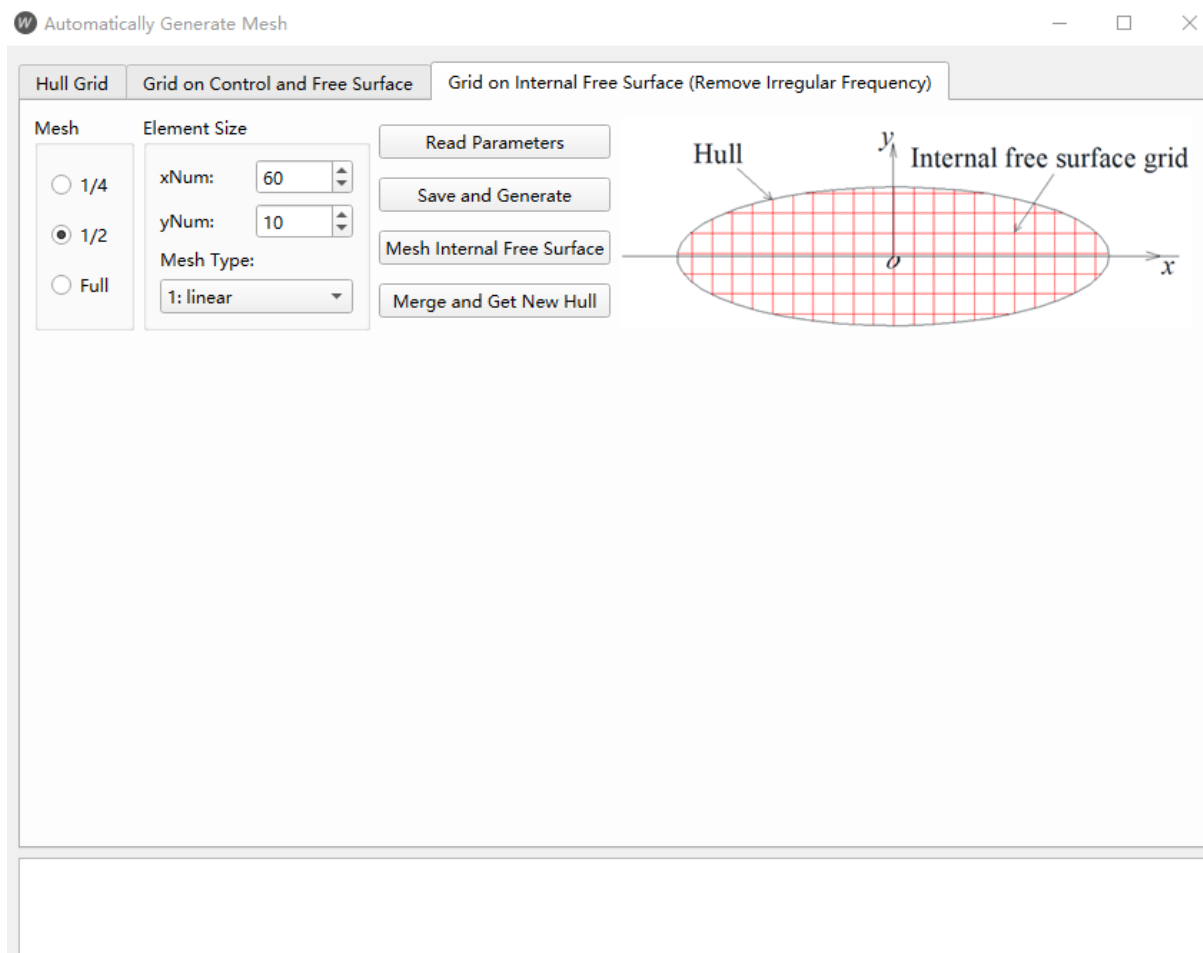


Fig. 19 Meshing on internal free surface





### 3.2.2. Splitting grid

**Splitting Grid**

Grid Model:

**Basic Parameters**

Roll [Deg.]:  Pitch [Deg.]:  Yaw [Deg.]:

Still Water Surface [m]:

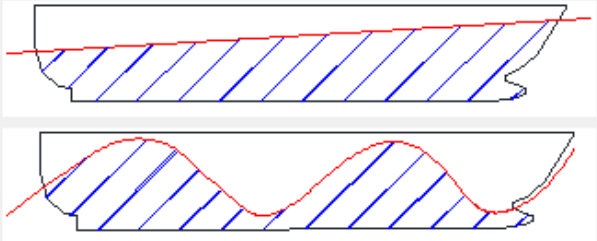
**Regular Wave**

☐ Regular Wave Wave Direction [Deg.]:  Freq. [rad/s]:  Time [s]:

Wave Amplitude [m]:  x [m]:  y [m]:  Water Depth [m]:

☐ Animate ☐ Suspend ☐ Record

☐ Reserve part upper still water line



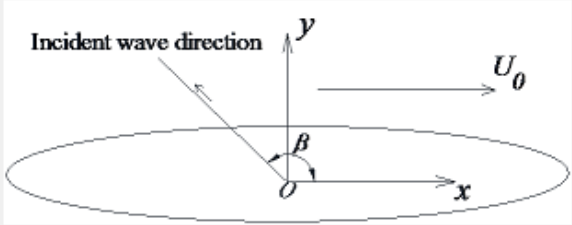


Fig. 20 Splitting grid



### 3.2.3. Natural frequency prediction of uniform straight beam

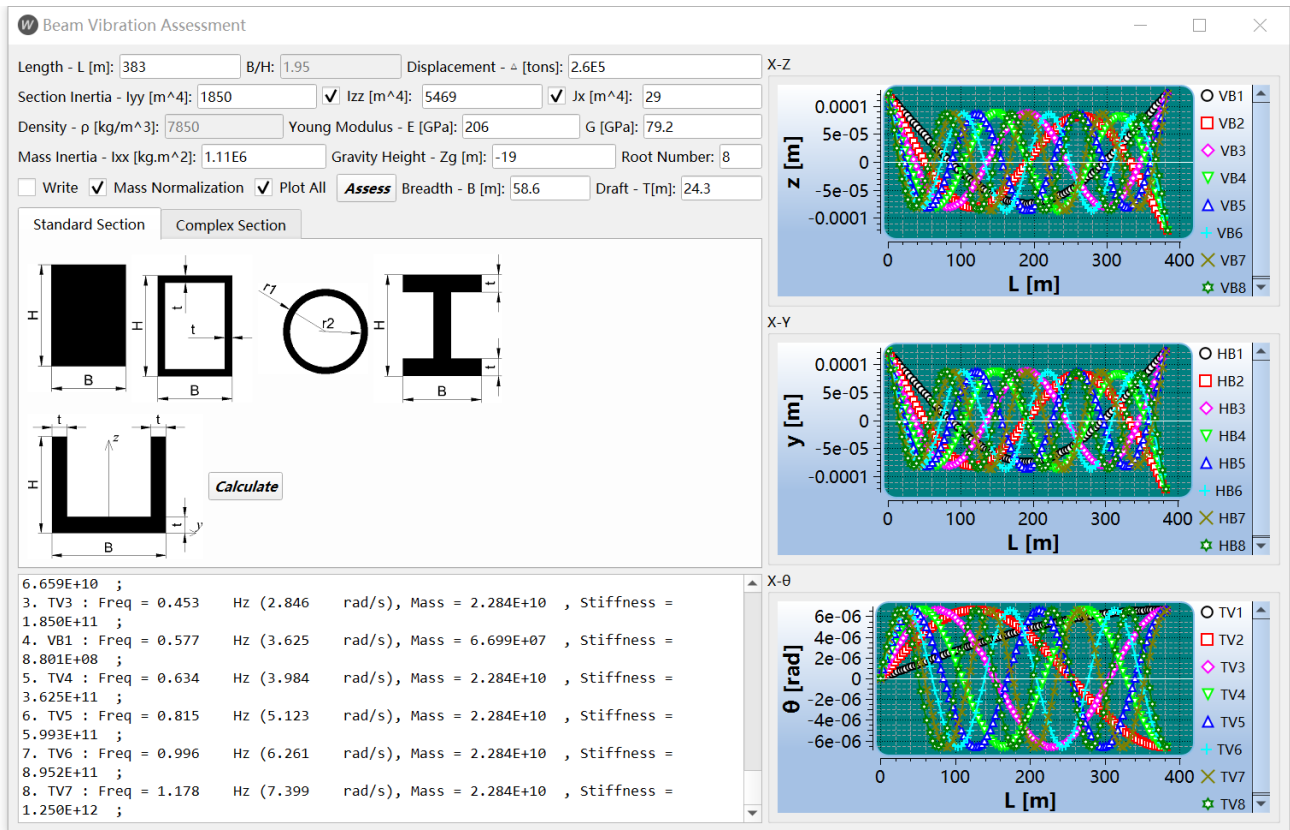


Fig. 21 Natural frequency prediction



## 3.3. Input parameters

### 3.3.1. Set working directory

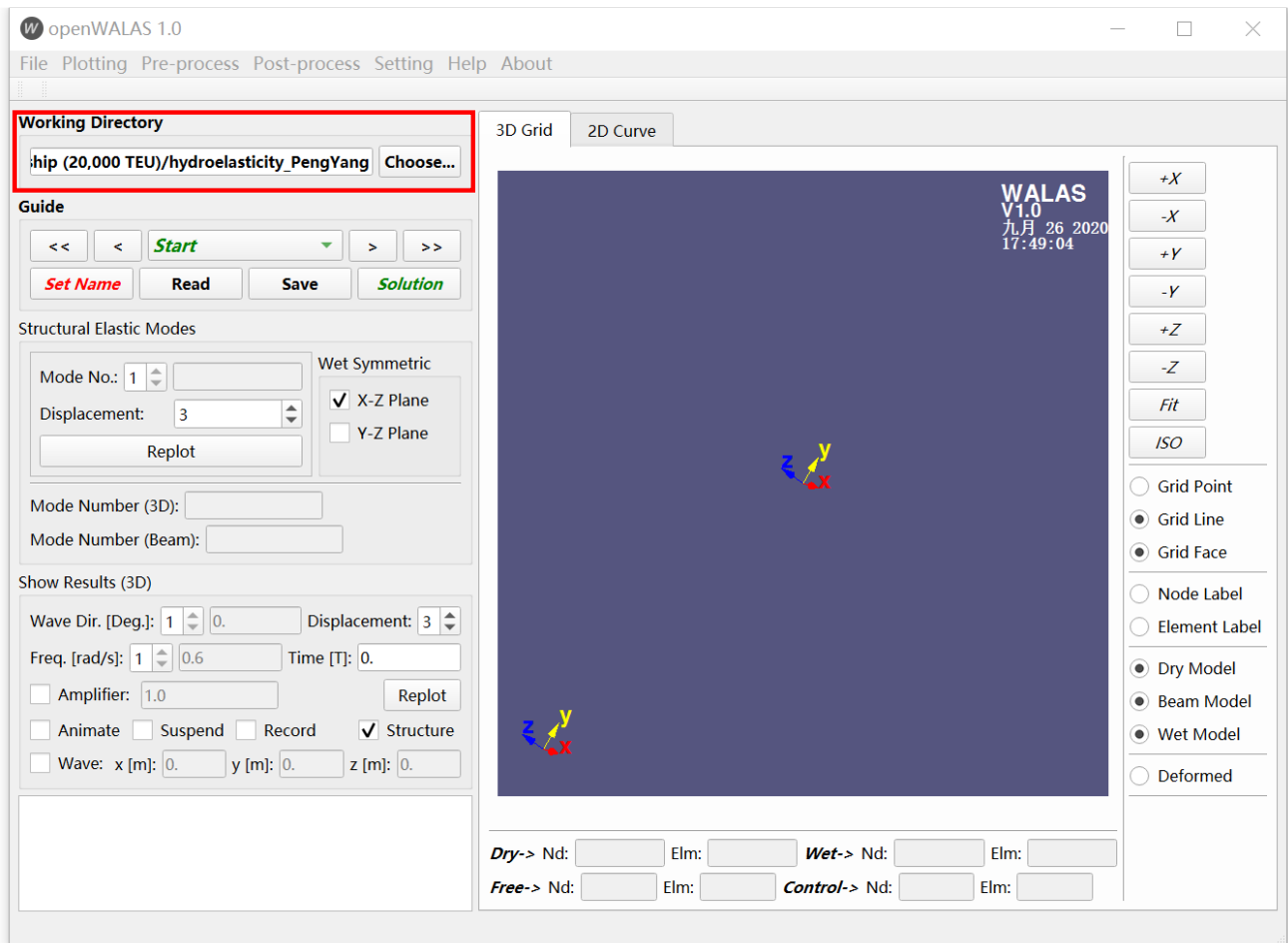
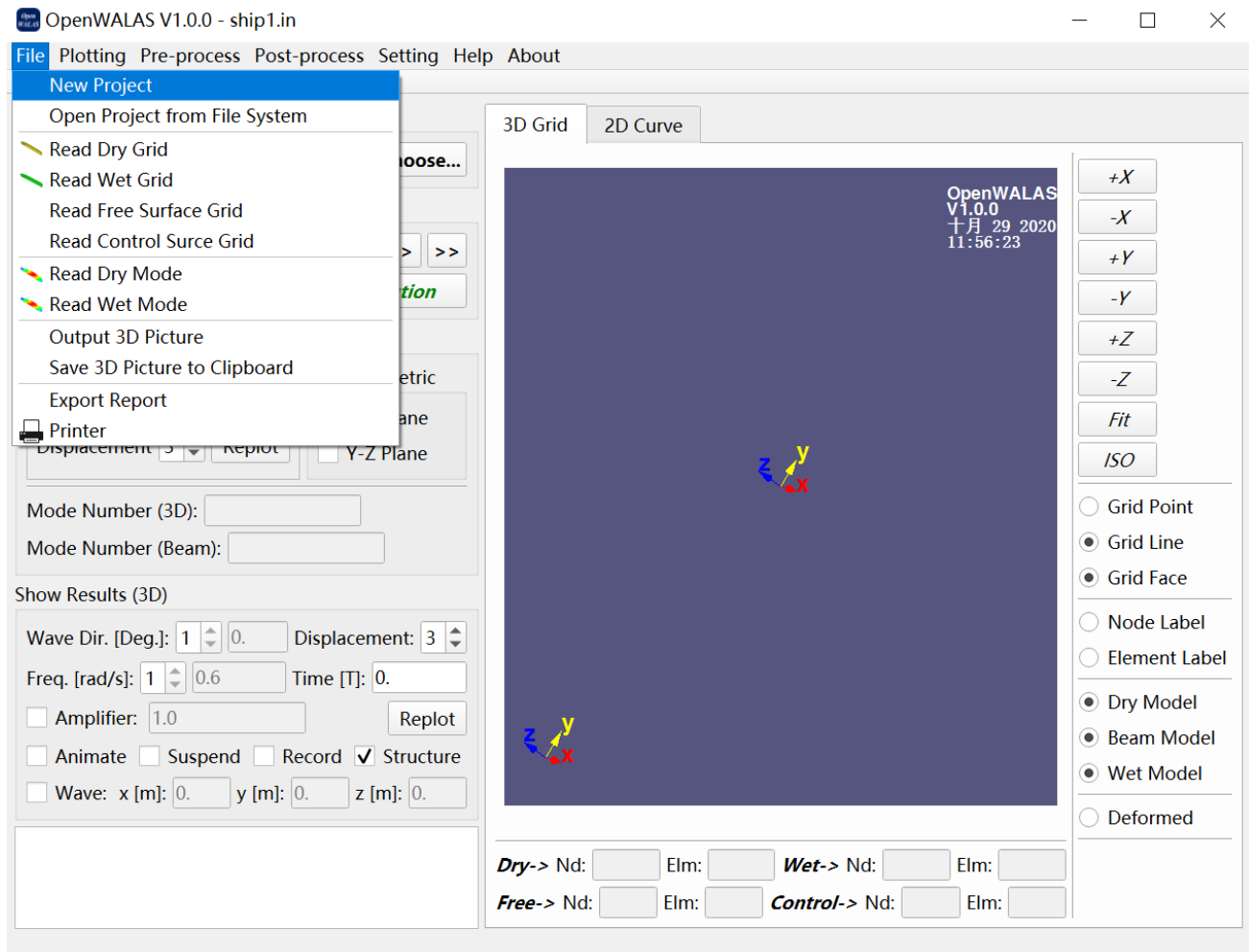


Fig. 22 Working directory



### 3.3.2. New Project





Model Configuration

Input File (main):

Basic Configuration   Control Parameters   Multi models   Connectors

Parallel Processing on Thread-level

Frequency Level:

Element Level:

☒ Restart to Calculate Hydrodynamic Coefficient

Wave Parameters:

Wave Sets   Initial Conditions

Case Number:    Modal Number:

Wave Type is  
0: Regular wave;  
1: Irregular wave - JONSWAP  
2: Irregular wave - P-M

Case Name	Wave Type	Hs [m]	Tz or Tp [s]	$\gamma$	Wave Number	Random Seed	Eval Time	Total time [s]	Time Start [s]	Time End [s]
1										

Fig. 23 Create new file of project (case.ini)



### 3.3.3. Set a file name of floating structure



Fig. 24 Set file name

### 3.3.4. Step 1 – Grid models and modal shapes

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



Step 1 - Grid and Modal

Nastran Results Input (\*.bdf and \*.f06, Only for hydroelastic analysis) Dry Grid and Mode Wet Grid Model

Dry Grid (.bdf):  Open...

Dry Mode (.f06):  Open...

Wet Grid

Wet Grid (.bdf):  Open...

☒ X-Z Plane

☐ Y-Z Plane

The coordinate systems of dry structural model and wet model:  
x minus axis points to bow, y minus axis points to port, z minus axis points to above, which obeys right-hand rule.  
The origin of dry structural model in the wet model coordinate system is:

x [m]:  y [m]:  z [m]:  Torsion Center [m]:

☐ Include Rigid Modes ☐ Continuous Modes Elastic Modal Amount:  Distrete List:

☒ Overwrite

Pre-Calculate

Main Informations

Lpp [m]:

Water Line Z [m]:

☒ About Gravity Center ☐ Pressure

☐ About Calm Surface Center ☐ Wave High

Parameters in Time Domain

Start Time (non-dimension):

End Time (non-dimension):

Interval Time (non-dimension):

Fig. 25 Dry and wet models

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



Step 1 - Grid and Modal

.bdf and \*.f06, Only for hydroelastic analysis) Dry Grid and Mode Wet Grid Model Free and Control Surface

Grid Model of Free Surface (.bdf) freeSurface.bdf Choose Generate

Grid Model of Control Surface (.bdf) controlSurface.bdf Choose Generate

**Notes: only needed for IORM method in time domain (Inner and Outer Region Matching method)**

☒ Overwrite

Pre-Calculate

Main Informations

Lpp [m]: 300

Water Line Z [m]: 0.0

☒ About Gravity Center ☐ Pressure

☐ About Calm Surface Center ☐ Wave High

Parameters in Time Domain

Start Time (non-dimension): -4.0

End Time (non-dimension): 4.0

Interval Time (non-dimension): 0.05

Fig. 26 Free surface and control surface models

### 3.3.5. Step 2 - gravity center and Inertia

Step 2

Center of Gravity

x [m]: 0.0 y [m]: 0.0 z [m]: 0.0

Model Inertia

lxx [kg.m<sup>2</sup>]: 0.0 lyy [kg.m<sup>2</sup>]: 0.0 lzz [kg.m<sup>2</sup>]: 0.0

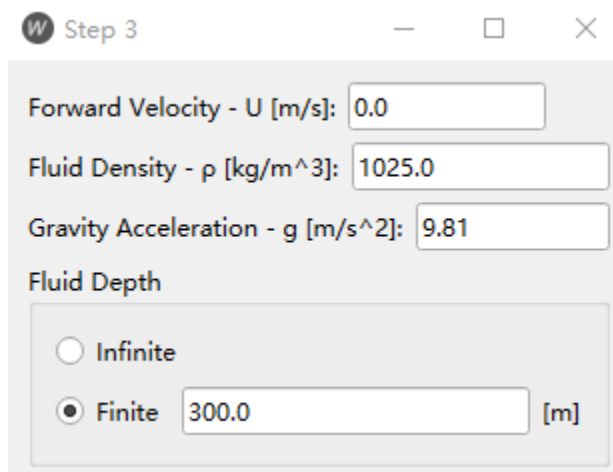
lxy [kg.m<sup>2</sup>]: 0.0 lxz [kg.m<sup>2</sup>]: 0.0 lyz [kg.m<sup>2</sup>]: 0.0

Fig. 27 Step 2





### 3.3.6. Step 3 - forward speed, fluid density, gravity acceleration and water depth



Step 3

Forward Velocity -  $U$  [m/s]: 0.0

Fluid Density -  $\rho$  [kg/m<sup>3</sup>]: 1025.0

Gravity Acceleration -  $g$  [m/s<sup>2</sup>]: 9.81

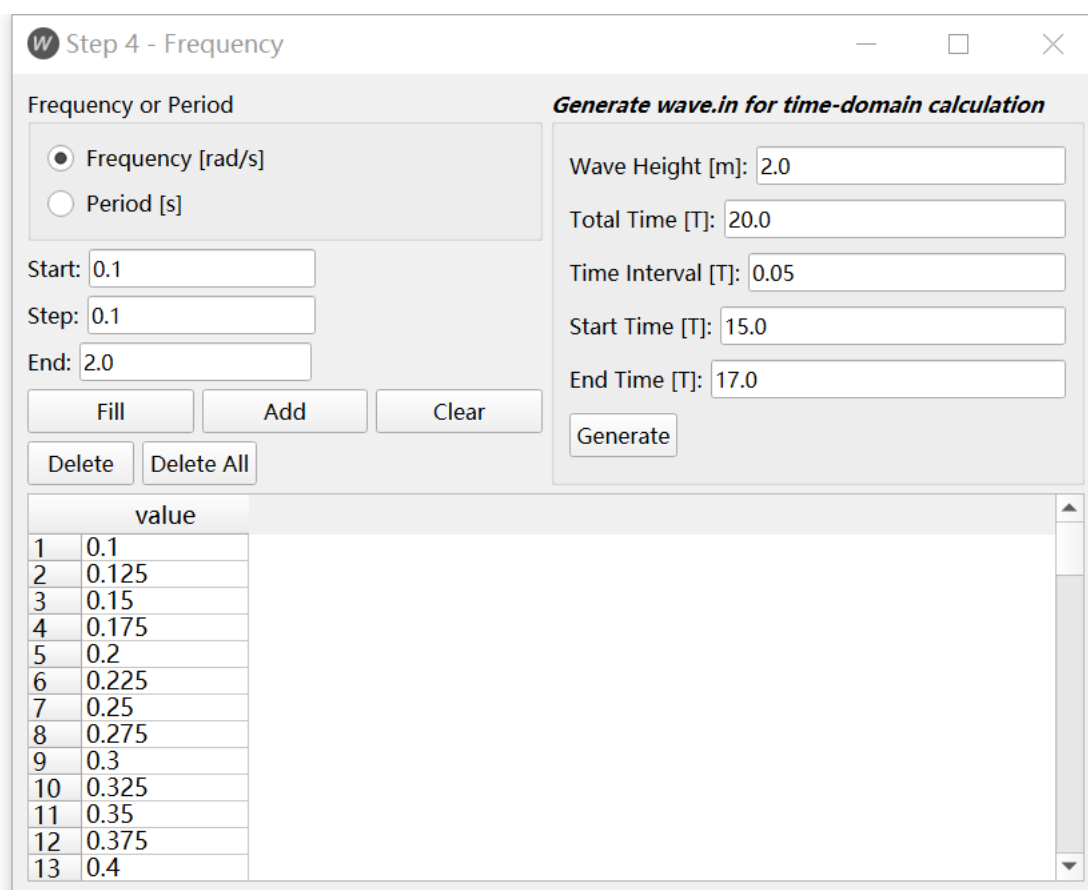
Fluid Depth

☐ Infinite

☒ Finite 300.0 [m]

Fig. 28 Step 3

### 3.3.7. Step 4 - wave frequencies and periods



Step 4 - Frequency

Frequency or Period

☒ Frequency [rad/s]

☐ Period [s]

Start: 0.1

Step: 0.1

End: 2.0

Fill Add Clear

Delete Delete All

**Generate wave.in for time-domain calculation**

Wave Height [m]: 2.0

Total Time [T]: 20.0

Time Interval [T]: 0.05

Start Time [T]: 15.0

End Time [T]: 17.0

Generate

	value
1	0.1
2	0.125
3	0.15
4	0.175
5	0.2
6	0.225
7	0.25
8	0.275
9	0.3
10	0.325
11	0.35
12	0.375
13	0.4

Fig. 29 Step 4



### 3.3.8. Step 5 - wave directions

Wave Direction:

Start: 0

Step: 45

End: 180

Fill Add Delete Delete All Clear

Angle [Deg.]

Fig. 30 Step 5



### 3.3.9. Step 6 - interpolation and artificial damping coefficient

Step 6

Frequency number for interpolation: 500

☐ Include Rigid Modal

Viscous Damping Coefficients of Rigid Motions:

C11:	0.0	C22:	0.0
C33:	0.0	C44:	0.0
C55:	0.0	C66:	0.0

Viscous Damping Coefficients of Elastic Modals:

Number: 0

Same Value: 0.05

Fill Add Delete Delete All Clear

Value
-------

Fig. 31 Step 6

### 3.3.10. Step 7 - mass distribution and section positions for wave load calculation

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.



Step 7

### Mass Points Distribution

☐ From File:

☒ Input number:

Mass [kg]	x [m]	y [m]	z [m]	Ixx [kg.m^2]
-----------	-------	-------	-------	--------------

### Wave Load Sections

☐ From File:

☒ Input number:

x [m]	y [m]	z [m]
-------	-------	-------

### Inertia Matrix (Above)

Mass:  COG:

X	0.	0.	0.	0.
Y	0.	0.	0.	0.
Z	0.	0.	0.	0.

Fig. 32 Step 7

### 3.3.11. Step 8 – Spring or Mooring Line

Springer or Mooring Line

☒ Artificial Springer  
☐ Mooring Line

K11:  K22:  K33:   
K44:  K55:  K66:

### Points Definition

☐ Wet Model ☒ Dry Model

Number:

No.	x [m]	y [m]	z [m]
-----	-------	-------	-------

### Mooring Lines

Number:

Type	Point 1	Point 2	K (N/m)	Length (m)
------	---------	---------	---------	------------

Fig. 33 Step 8



## 3.4. Solution

**Model Configuration**

Input File (main):

Basic Configuration   Control Parameters   Multi models   Connectors

Parallel Processing on Thread-level

Frequency Level:

Element Level:

☒ Restart to Calculate Hydrodynamic Coefficient

Wave Parameters:

Wave Sets   Initial Conditions

Case Number:    Modal Number:

Wave Type is  
0: Regular wave;  
1: Irregular wave - JONSWAP  
2: Irregular wave - P-M

Case Name	Wave Type	Hs [m]	Tz or Tp [s]	$\gamma$	Wave Number	Random Seed	Interval Time	Total time [s]	Time Start [s]	Time End [s]
1										

Fig. 34 Configuration of models

**Solution**

**Configure Cases**

Frequency Domain - FSCM   Time Domain (TDGF & IORM)   Time-domain Responses

Input File (main):

☒ Rigid Motion   ☒ Elastic Deformation  

Fig. 35 Solution type



## 3.5. Post-process and show results

### 3.5.1. Basic information

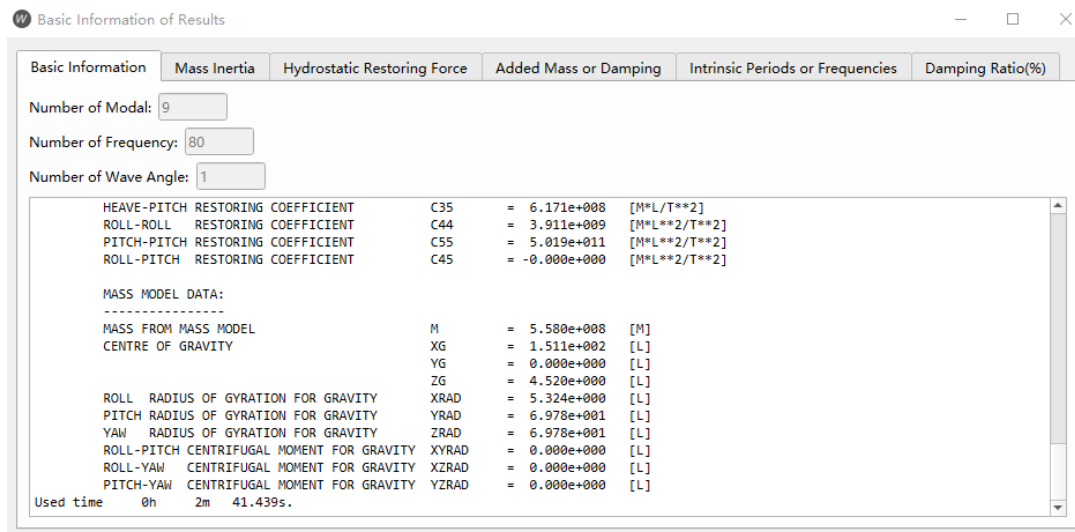


Fig. 36 Basic information

### 3.5.2. Results in frequency domain

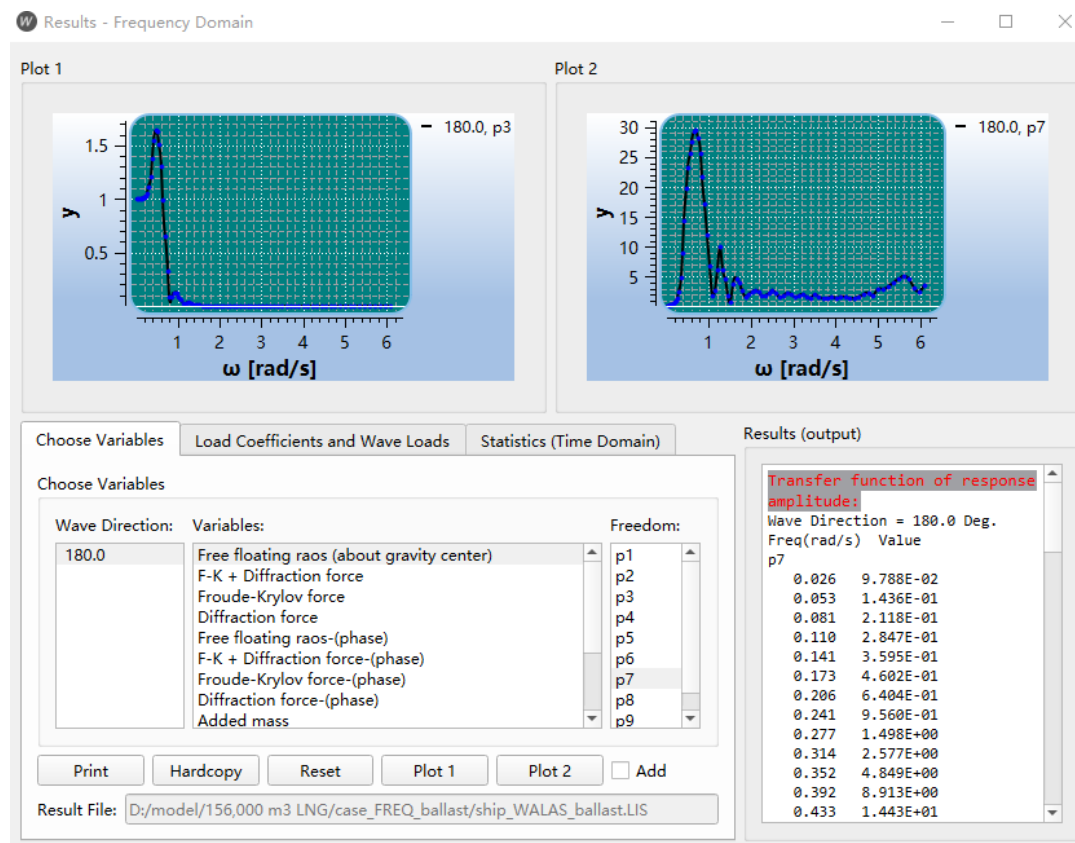


Fig. 37 Results in frequency domain



### 3.5.3. Results in time domain

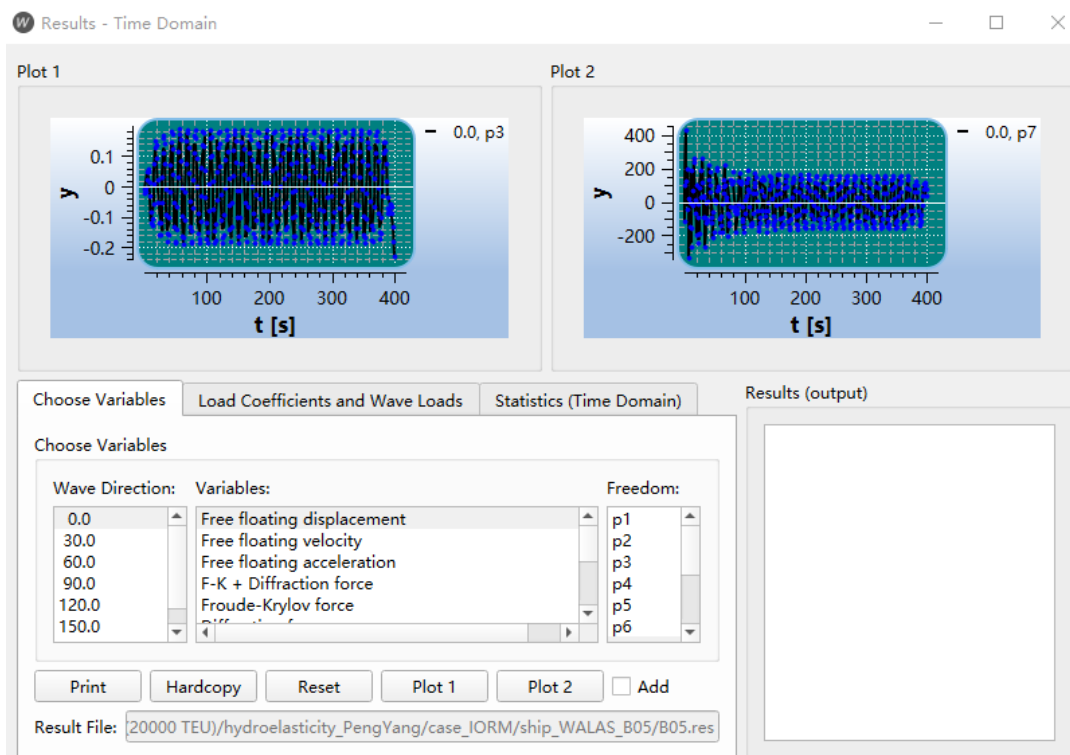


Fig. 38 Results in time domain

### 3.5.4. Predictions in short-term

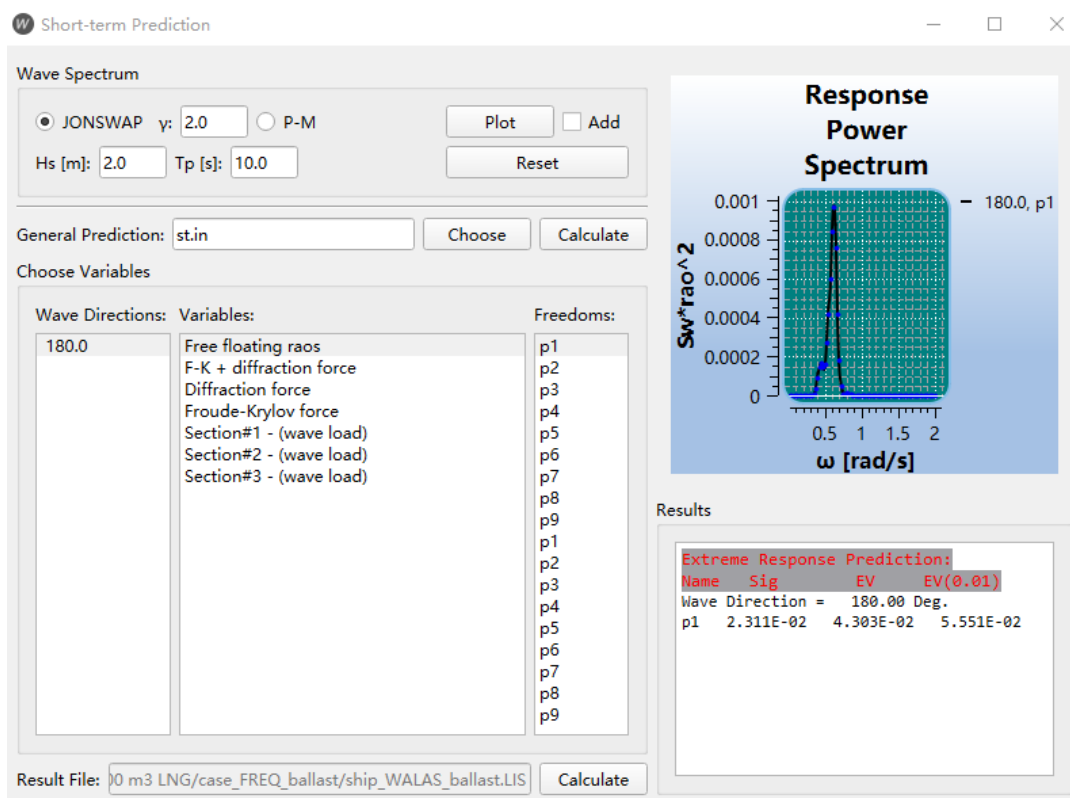


Fig. 39 Prediction in short-term



### 3.5.5. Predictions in long-term and fatigue analysis

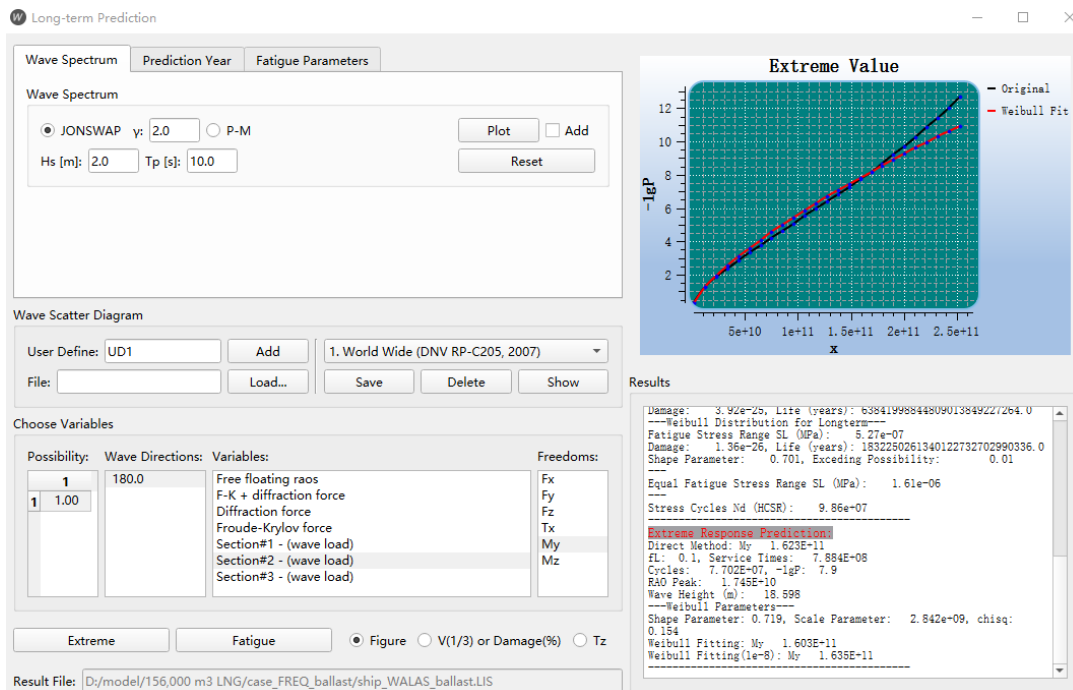


Fig. 40 Prediction in long-term

### 3.6. Basic definitions

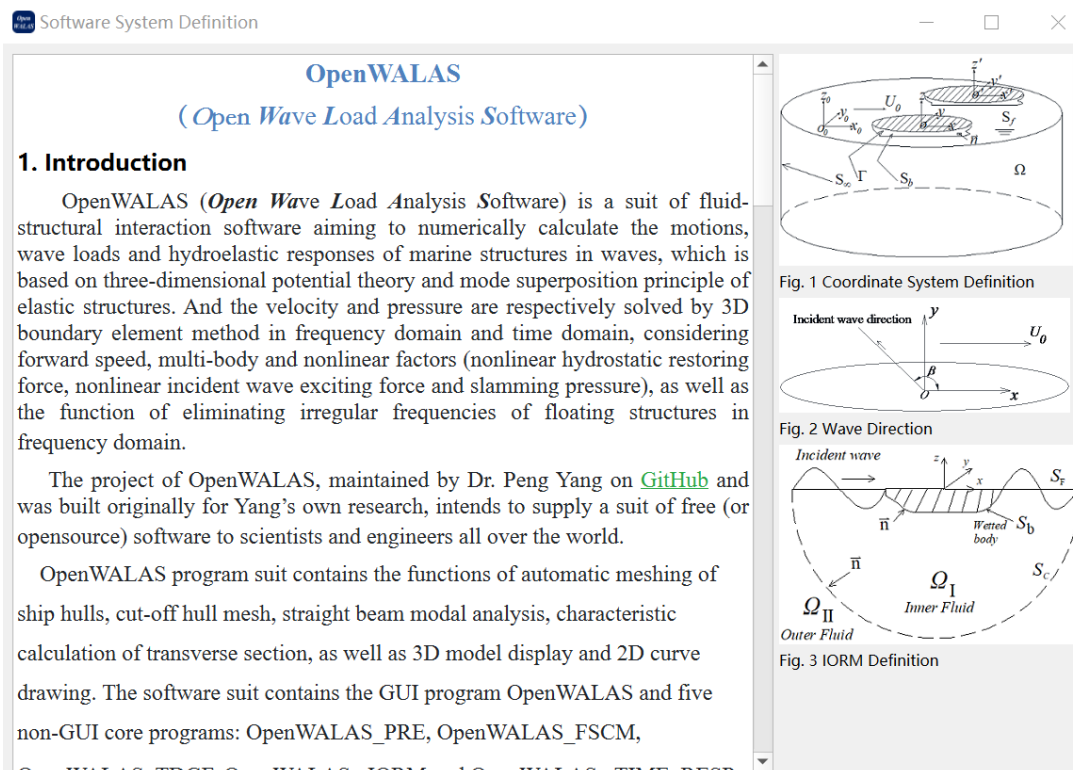


Fig. 41 Basic definition





## 4. Introduction of OpenWALAS non-GUI

### 4.1. Running sequences

1. Pre-process: *OpenWALAS\_PRE.exe case.ini 0(or 1)*
2. Solution
  - (a) *OpenWALAS\_FSCM.exe case.ini;*
  - (b) *OpenWALAS\_TDGF.exe case.ini;*
  - (c) *OpenWALAS\_IORM.exe case.ini;*
  - (d) *OpenWALAS\_TIME\_RESP.exe case.ini wave.in;*
3. Post-process: *OpenWALAS\_POST.exe case.ini 1 Y Y Y*

There are five input files: *case.ini*, *ship1.in*, *ship\_wet.bdf*, *ship\_dry.bdf*, *ship.f06*.

### 4.2. 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.

#### 4.2.1. Identity of input file

*JOB WALAS MULTI*

#### 4.2.2. Parameters of parallel calculation

*threadNumFreq threadNumElem*

*threadNumFreq*: thread number for parallel process (frequency parallel)

*threadNumElem*: thread number for parallel process (element parallel)

#### 4.2.3. Control parameters of hydrodynamic coupling among floating structures

*STRCNUM startCoupleNo*

*STRCNUM*: module number

*startCoupleNo*: module No. of starting coupling

#### 4.2.4. 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.



#### 4.2.5. 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.

#### 4.2.6. 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.

#### 4.2.7. Connector definition

*CONNUM*

*strcNo1 pointNo1 strcNo2 pointNo2 stiffness<sub>x</sub> stiffness<sub>y</sub> stiffness<sub>z</sub> stiffness<sub>Rx</sub> stiffness<sub>Ry</sub> stiffness<sub>Rz</sub>*

*CONNUM*: number of connectors

*strcNo1, strcNo2*: No. of floating structures

*pointNo1, pointNo2*: Node No.

*stiffness<sub>x</sub> stiffness<sub>y</sub> stiffness<sub>z</sub> stiffness<sub>Rx</sub> stiffness<sub>Ry</sub> stiffness<sub>Rz</sub>*: the stiffness of translation and rotation

#### 4.2.8. 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

### 4.3. Input parameters of floating structures (shipX.in)

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

#### 4.3.1. Identity

*JOB WALAS*

#### 4.3.2. File name of wet grid model

Enclosed in double quotation marks

#### 4.3.3. File name of dry grid model

Enclosed in double quotation marks

#### 4.3.4. Modal shapes of nodes of dry model

Enclosed in double quotation marks

#### 4.3.5. Modal shapes of elements of wet model

Enclosed in double quotation marks

#### 4.3.6. Information of dudx of wet model

Enclosed in double quotation marks

#### 4.3.7. File name of grid model of free surface

Enclosed in double quotation marks

Only affect for IORM method in time domain

#### 4.3.8. File name of grid model of virtual control surface

Enclosed in double quotation marks

Only affect for IORM method in time domain



#### 4.3.9. File name of slamming pressure

Enclosed in double quotation marks

Only affect in time domain

#### 4.3.10. 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.

#### 4.3.11. Coordinates of gravity center

*Xg Yg Zg*

Relative to wet coordinate system

Xg: x value

Yg: y value

Zg: z value

#### 4.3.12. Mass inertia

*Ixx Iyy Izz Ixy Ixz Iyz*



Relative to gravity center

Ixx: about  $x$  axis.

Iyy: about  $y$  axis

Izz: about  $z$  axis

Ixy: in  $x$ - $y$  plane.

Ixz: in  $x$ - $z$  plane

Iyz: in  $y$ - $z$  plane

#### 4.3.13. Position of dry coordinate origin in wet coordinate system

*Dryx Dryy Dryz Tz*

Dryx:  $x$  value

Dryy:  $y$  value

Dryz:  $z$  value

Tz: torsional center (or shear center) about neutral axis of vertical bending (only works in Beam model)

#### 4.3.14. Forward speed, density and acceleration of gravity

*Vel Rho G*

Forward speed, density of fluid, gravity acceleration.

#### 4.3.15. 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

#### 4.3.16. 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.

#### 4.3.17. 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.

#### 4.3.18. 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

#### 4.3.19. 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.

#### 4.3.20. 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



#### 4.3.21. Mass points for wave loading calculations

*massPointNum*

*mass[n] x[n] y[n] z[n] Ixx[n]*

.....

*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]*: the mass inertia about *x* axis.

#### 4.3.22. Section definitions of wave loads

*secNum waveLoadSymbol*

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

*secNum*: section number of wave loads

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

*waveLoadSymbol*: flag of integral for wave loads, -1: bow, 1 – stern. For the cases of “bow” integral, “-” denotes the sagging moment, and “+” denotes the hogging moment. on the contrary for the cases of “stern” integral.

#### 4.3.23. Spring or mooring line

(1) *Flag*

*Flag*: SPRING

(2) *MRL, moorPointFixedNum, wetDryFlagMoor*

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

*moorPointFixedNum*: number of mooring points

*wetDryFlagMoor*: type of mooring points, 0 – from wet model, 1 – from dry model. If including elastic modes, must be 1.

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

*Stiffness<sub>x</sub>, Stiffness<sub>y</sub>, Stiffness<sub>z</sub>, Stiffness<sub>R<sub>x</sub></sub>, Stiffness<sub>R<sub>y</sub></sub>, Stiffness<sub>R<sub>z</sub></sub>*



#### 4.3.24. 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		
0.000E+00	0.000E+00	-1.000E+00		
7.500E+00	0.000E+00	-1.000E+00		
SPRING				
0				
5e+05	5e+06	0	0	0
				1e+10

#### 4.4. Wave parameters of time-domain calculation (shipX\_wave.in)

##### 4.4.1. Case number

caseNum: number of cases



#### 4.4.2. Case name

Name of the case

#### 4.4.3. 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

#### 4.4.4. 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
---------	---------	---------	---------

#### 4.4.5. Initial conditions of each mode

$N$  - Number of initial conditions

*Displacement1   Velocity1*

*Displacement2   Velocity2*

*Displacement3   Velocity4*

...

*DisplacementN   VelocityN*

#### 4.4.6. 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			
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			
0	0			

#### 4.5. 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.

##### 4.5.1. Formulas of slamming pressure

*No*: Number of discrete points of the formulas



$x_n$   $y_n$ : coordinates of  $x$  and  $y$  of the points

**Example:**

$N_o$

$x_1$   $y_1$

$x_2$   $y_2$

$x_3$   $y_3$

...

$x_n$   $y_n$

#### 4.5.2. Definition of slamming areas

$X_1$ : from stern to  $x_1$ , considering slamming

$X_2$ : from  $x_2$  to bow, considering slamming

$N_o$ : 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)

$Point_1$ : element #1

$Point_2$ : element #2

$Point_3$ : element #3

**Example:**

$X_1$   $x_2$

$N_o$

$Point_1$

$Point_2$

...

$Point_N$

#### 4.5.3. Example

3

1.0 20.

2.0 24.



3.0 50.

50 330

3

147

148

149

#### **4.6. 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.

#### **4.7. 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.

#### **4.8. 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. Output instructions

### 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. 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)`
2. `createhull(ansys)`
3. `createElem(patran)`
4. `createhull(patran)`
5. `getModal(ansys)`
6. `getNodeElement(ansys)`
7. `bdf2WALAS` – transfer grid model form .bdf file of Patran to OpenWALAS

And the “`shorterm`” program is for response prediction in short-term sea states.

## References

- [1] Wu, Y.S., 1984, Hydroelasticity of floating bodies. Ph.D., Thesis, *Brunel University*, U.K.
- [2] Yang, P., Gu, X.K., Tian, C., Cheng, X.M., Ding, J., 2014. Numerical Study of 3D Pulsating Source Green Function of Finite Water Depth, *Proceedings of the 33th International Conference on Ocean, Offshore and Arctic Engineering (OMAE)*, San Francisco, California, USA, June.
- [3] Yang, P., 2016. 3D Nonlinear Hydro-elastic Response Study of Ships in Time Domain (*Doctoral thesis*). China Ship Scientific Research Center, Wuxi, China. (In Chinese).
- [4] Yang, P., Ye, M.X., Li, J.C., et al., 2018. Mathematical derivation of simplified calculation of symmetrical green function. *Chinese Journal of Ship Research*, 13(Supp 1): 22-28.
- [5] Yang, P., Kou, G.Y., Zhu, X.K., et al., 2019. Numerical calculation method for wave loads of floating structures in shallow water. *Chinese Journal of Ship Research*, 14(1): 19-26.
- [6] Yang, P., Li, J.R., Gu, X.K., Wu, D.W., 2019. Application of the 3D time-domain Green's function for finite water depth in hydroelastic mechanics. *Ocean Engineering*, 189.
- [7] Yang, P., Li, J.R., Wu, D.W., Zhang, W., 2020. Irregular Frequency Elimination of Three-Dimensional Hydroelasticity in Frequency Domain. *Ocean Engineering*, 196.
- [8] GSL - GNU Scientific Library. 2019. <http://www.gnu.org/software/gsl/>.
- [9] Qt. 2019. <https://www.qt.io/>.
- [10] Qwt. 2019. <http://qwt.sourceforge.net/>.
- [11] Opencv. 2019. <https://opencv.org/>.