User-manual of F2A

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This is a detailed manual of FAST2AQWA(F2A) that is a fully coupled aero-hydro-servo-elastic modelling tool developed in AQWA by incorporating FAST v7 within AQWA. This manual describes how to model a floating offshore wind turbine (FOWT) using F2A step-by-step. The NREL 5 MW wind turbine supported by the DeepCWind semisubmersible platform is selected as the case study.

1. Required input files of F2A

The coupling between FAST and AQWA is achieved through the user_force64.dll that will be invoked by AQWA solver for calculating external force. Fig. 1 presents the logical flowchart of F2A. The dynamic responses of a FOWT are predicted in different modules. More specifically, the dynamic responses of the upper structures (red frame in Fig. 2) are predicted in the DLL. The responses of the platform (blue frame in Fig. 2) are calculated in AQWA solver by considering the external force fed by the DLL.

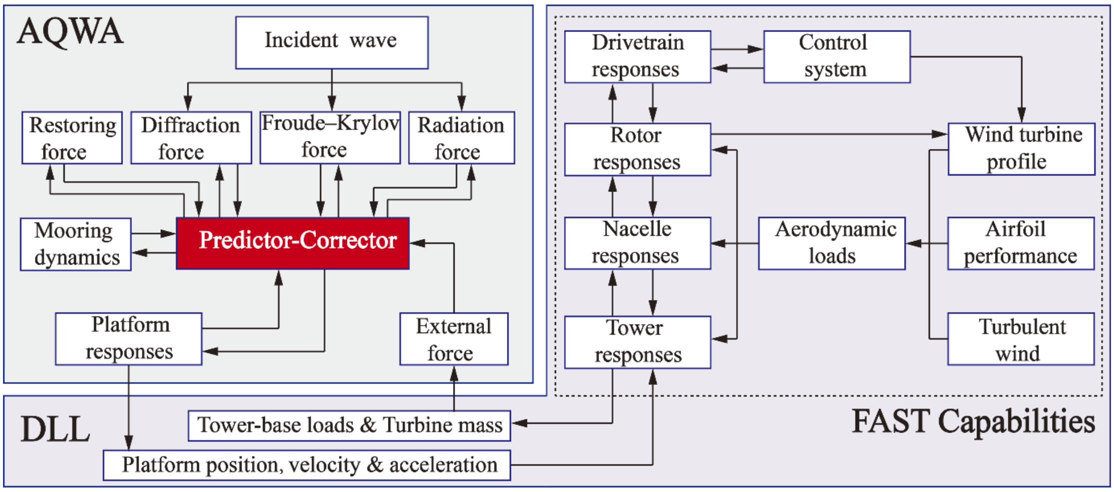


Fig. 1: Flowchart of F2A

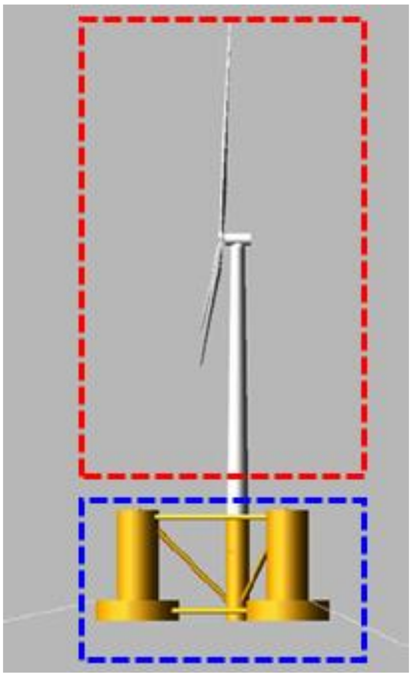
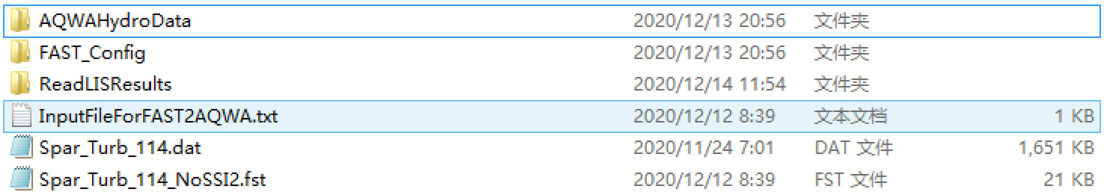


Fig. 2: Upper structures (red frame) and platform (blue frame) of a FOWT

I have uploaded an example of F2A that is for the NREL 5 MW Spar wind turbine in the “Examples” directory of F2A repository which can be found via the link: https://github.com/yang7857854/F2A/tree/main/Examples.

As shown in Fig. 3, a F2A case includes 4 groups of inputs: 1) AQWA input; 2) FASTv7 input; 3) ReadLISResult and 4) Input for F2A. These inputs are explained in Table 1.



AQWAHydroData	2020/12/13 20:56	文件夹	
FAST_Config	2020/12/13 20:56	文件夹	
ReadLISResults	2020/12/14 11:54	文件夹	
InputFileForFAST2AQWA.txt	2020/12/12 8:39	文本文档	1 KB
Spar_Turb_114.dat	2020/11/24 7:01	DAT 文件	1,651 KB
Spar_Turb_114_NoSSI2.fst	2020/12/12 8:39	FST 文件	21 KB

Fig. 3: F2A case files of NREL 5 MW spar

Table 1: Descriptions of the F2A example case

Group	Contains	Description
AQWA input	AQWAHydroData\	Directory of hydrodynamic data of the platform (extension of .hyd) generated by AQWA
	AQWAHydroData\SPARFREQ_NEW.HYD	Hydrodynamic data from frequency domain analysis performed in AQWA
	AQWAHydroData\ SPARFREQ.MQT	Binary file of quadratic transfer function (QTF) of the platform
	AQWAHydroData\ SPARFREQ.QTF	ASCII file of quadratic transfer function (QTF) of the platform
	Spar_Turb_114.dat	Input of AQWA time response simulation. This is generated by Workbench.

FASTv7 input	FAST_Config\	Directory of other inputs of FAST
	FAST_Config\AeroData\	Directory of aerodynamic performance file of blade airfoils
	FAST_Config\ServoData\	Directory of servo-control DLLs of the wind turbine
	FAST_Config\WindData\	Directory of wind field
	FAST_Config\NRELOffshrBsline5MW_ADAMSSpecific.dat	Specifications of ADAMS configurations when FAST is run as the ADAMS's preprocessor
	FAST_Config\NRELOffshrBsline5MW_AeroDyn.ipt	AeroDyn input that contains wind field directory and blade aerodynamic shape
	FAST_Config\Other .ipt files	AeroDyn inputs for different wind conditons
	FAST_Config\NRELOffshrBsline5MW_Blade.dat	Structural property of the blade
	FAST_Config\NRELOffshrBsline5MW_Linear.dat	Linearization configurations
	FAST_Config\NRELOffshrBsline5MW_Platform_OC3Hywind_AQWA.dat	Platform file
	FAST_Config\NRELOffshrBsline5MW_Spar_TMDControl.dat	TMD control configurations
	FAST_Config\NRELOffshrBsline5MW_Tower_OC3Hywind.dat	Structural property of the tower
	Spar_Turb_114_NoSSI2.fst	Primary input file of FAST v7
ReadLIS Result	ReadLISResult\	Read results in the .lis file generated after a AQWA simulation
	ReadLISResult\InputforreadAQWAResults_SingleFile.txt	Input file for the code of reading the results in LIS file
	ReadLISResult\readAQWAResults_SingleFile.exe	Code of reading the results in LIS file
Input for F2A	InputFileForFAST2AQWA.txt	Input file that will be opened by F2A to read the primary input of FAST

2. Download reference documents and basic input files of the FOWT

In order to run a F2A simulation, we need get the essential input files listed in Table 1 prepared. For the wind turbine part, we need the basic information of the blades, tower and nacelle, etc. These information can be obtained from reference OpenFAST models of the NREL 5MW wind turbine that can be found and downloaded via this link: https://github.com/OpenFAST/r-test. The relevant input files of the DeepCWind tests will be used. In addition, we also need to model the platform in AQWA. The geometry and inertial properties of the platform are required. The main specifications of the DeepCWind semisubmersible platform are presented in https://www.nrel.gov/docs/fy14osti/60601.pdf.

3. Transition to FAST v7

Different from the modularized OpenFAST in which the configuration of each main component of the wind turbine is defined in an individual file, the primary input file of FAST v7 contain the definitions of each structural component. In the DeepCwind case study, the only modifications that need to be made on the example .fst given in F2A repository are related to the platform and tower as shown in Fig. 3.

```
---------------------- PLATFORM -----------------------------------------
   1         PtfmModel    - Platform model {0: none, 1: onshore, 2: fixed bott
"FAST_Config\NRELOffshrBsline5MW_Platform_OC3Hywind_AQWA.dat"     PtfmFile
---------------------- TOWER --------------------------------------------
  20         TwrNodes     - Number of tower nodes used for analysis (-)
"FAST_Config\NRELOffshrBsline5MW_Tower_OC3Hywind.dat"          TwrFile      - N
---------------------- NACELLE-YAW --------------------------------------
```

Fig. 3: Platform and tower settings in FAST's primary input file

The "PtfmModel" must be set to 1. Fig. 4 presents the structure of the platform file corresponding to the OC3Hywind model. For an arbitrary model, the six DOFs of the platform must be enabled as same as the example. In addition, the tower draft needs to be set correctly. The downward direction is the positive direction of tower draft. For example, the correct tower draft of the Hywind model is -10 m, meaning that the tower base is placed at the position with 10 meter higher than the mean sea level (MSL). In other words, the platform's top surface is 10 meter higher than the MSL. Other parameters including the platform's CM and inertial properties will be ignored. The contents in this file below the line "PtfmLDMod" will be ignored. You can remove all lines below that line if you would like to.

```
NRELOffshrBsline5MW_Platform_OC3Hywind_AQWA.dat - 记事本
文件(F)  编辑(E)  格式(O)  查看(V)  帮助(H)
--------------------------------------------------------------------------------
---------------------- FAST PLATFORM FILE --------------------------------------
NREL 5.0 MW offshore baseline floating platform input properties for the OC3-Hywind spar-buoy.
---------------------- FEATURE FLAGS (CONT) ------------------------------------
True         PtfmSgDOF    - Platform horizontal surge translation DOF (flag)
True         PtfmSwDOF    - Platform horizontal sway translation DOF (flag)
True         PtfmHvDOF    - Platform vertical heave translation DOF (flag)
True         PtfmRDOF     - Platform roll tilt rotation DOF (flag)
True         PtfmPDOF     - Platform pitch tilt rotation DOF (flag)
True         PtfmYDOF     - Platform yaw rotation DOF (flag)
---------------------- INITIAL CONDITIONS (CONT) -------------------------------
   0.0       PtfmSurge    - Initial or fixed horizontal surge translational displacement of platform (meters)
   0.0       PtfmSway     - Initial or fixed horizontal sway translational displacement of platform (meters)
   0.0       PtfmHeave    - Initial or fixed vertical heave translational displacement of platform (meters)
   0.0       PtfmRoll     - Initial or fixed roll tilt rotational displacement of platform (degrees)
   0.0       PtfmPitch    - Initial or fixed pitch tilt rotational displacement of platform (degrees)
   0.0       PtfmYaw      - Initial or fixed yaw rotational displacement of platform (degrees)
---------------------- TURBINE CONFIGURATION (CONT) ----------------------------
 -10.0       TwrDraft     - Downward distance from the ground level [onshore] or MSL [offshore] to the tower base platform connection (meter
  89.9155    PtfmCM       - Downward distance from the ground level [onshore] or MSL [offshore] to the platform CM (meters)
  0.0       PtfmRef      - Downward distance from the ground level [onshore] or MSL [offshore] to the platform reference point (meters)
---------------------- MASS AND INERTIA (CONT) ---------------------------------
0.0     7466.33E3   PtfmMass    - Platform mass (kg)
0.0E6   PtfmRIner   - Platform inertia for roll tilt rotation about the platform CM (kg m^2)
0.0E6   PtfmPIner   - Platform inertia for pitch tilt rotation about the platform CM (kg m^2)
0.0E6   PtfmYIner   - Platfrom inertia for yaw rotation about the platform CM (kg m^2)
---------------------- PLATFORM (CONT) -----------------------------------------
0  PtfmLdMod   - Platform loading model {0: none, 1: user-defined from routine UserPtfmLd} (switch)
"HydroData\Spar"                           WAMITFile     - Root name of WAMIT output files containing the linear, nondimensionalized,
(.hst extension), frequency-dependent hydrodynamic added mass matrix and damping matrix (.1 extension), and frequency- and direction-depen
vector per unit wave amplitude (.3 extension) (quoted string) [MAKE SURE THE FREQUENCIES INHERENT IN THESE WAMIT FILES SPAN THE PHYSICALLY
FREQUENCIES FOR THE GIVEN PLATFORM; THEY MUST CONTAIN THE ZERO- AND INFINITE-FREQUENCY LIMITS!]
```

Fig. 4: An example of the platform file

The tower of the DeepCWind model is slightly different from that of the Hywind model. In the DeepCwind case study, we need to change the tower property file. We can use the "NRELOffshrBsline5MW_OC4DeepCwindSemi_ElastoDyn_Tower.dat" file given in a test directory of OC4Semi-sub of OpenFAST. However, the data structure of the tower property file of OpenFAST and FAST v7 is slightly different, as shown in Fig. 5. In FAST v7's model, there are there headlines, while there are only two headlines of the OpenFAST model. In addition, the line "False   CalcTMode   - Calculate tower mode shapes internally {T: ignore mode shapes from below, F: use mode shapes from below} [CURRENTLY IGNORED] (flag)" must be added into the FAST v7 tower file. Otherwise, there will be an error when F2A is trying to read parameters in the tower file.

```
------------------------------------------------------------------------------------
---------------------- FAST TOWER FILE ---------------------------------------------
NREL 5.0 MW offshore baseline tower input properties for the OC3-Hywind spar-buoy.
---------------------- TOWER PARAMETERS --------------------------------------------
  11        NTwInpSt    - Number of input stations to specify tower geometry
False       CalcTMode   - Calculate tower mode shapes internally {T: ignore mode shap
   1.0      TwrFADmp(1) - Tower 1st fore-aft mode structural damping ratio (%)
   1.0      TwrFADmp(2) - Tower 2nd fore-aft mode structural damping ratio (%)
   1.0      TwrSSDmp(1) - Tower 1st side-to-side mode structural damping ratio (%)
   1.0      TwrSSDmp(2) - Tower 2nd side-to-side mode structural damping ratio (%)
---------------------- TOWER ADJUSTMUNT FACTORS ------------------------------------
   1.0      FAStTunr(1) - Tower fore-aft modal stiffness tuner, 1st mode (-)
   1.0      FAStTunr(2) - Tower fore-aft modal stiffness tuner, 2nd mode (-)
   1.0      SSStTunr(1) - Tower side-to-side stiffness tuner, 1st mode (-)
   1.0      SSStTunr(2) - Tower side-to-side stiffness tuner, 2nd mode (-)
   1.0      AdjTwMa     - Factor to adjust tower mass density (-)
   1.0      AdjFASt     - Factor to adjust tower fore-aft stiffness (-)
   1.0      AdjSSSt     - Factor to adjust tower side-to-side stiffness (-)
---------------------- DISTRIBUTED TOWER PROPERTIES --------------------------------
HtFract  TMassDen  TwFAStif   TwSSStif   TwGJStif   TwEAStif   TwFAIner  TwSSIner  Tw
(-)      (kg/m)    (Nm^2)     (Nm^2)     (Nm^2)     (N)        (kg m)    (kg m)    (m
0.0      4667.00   603.903E9  603.903E9  464.718E9  115.302E9  24443.7   24443.7   0.
0.1      4345.28   517.644E9  517.644E9  398.339E9  107.354E9  20952.2   20952.2   0.
0.2      4034.76   440.925E9  440.925E9  339.303E9   99.682E9  17847.0   17847.0   0.
0.3      3735.44   373.022E9  373.022E9  287.049E9   92.287E9  15098.5   15098.5   0.
0.4      3447.32   313.236E9  313.236E9  241.043E9   85.169E9  12678.6   12678.6   0.
0.5      3170.40   260.897E9  260.897E9  200.767E9   78.328E9  10560.1   10560.1   0.
0.6      2904.69   215.365E9  215.365E9  165.729E9   71.763E9   8717.2    8717.2   0.
0.7      2650.18   176.028E9  176.028E9  135.458E9   65.475E9   7124.9    7124.9   0.
0.8      2406.88   142.301E9  142.301E9  109.504E9   59.464E9   5759.8    5759.8   0.
0.9      2174.77   113.630E9  113.630E9   87.441E9   53.730E9   4599.3    4599.3   0.
1.0      1953.87    89.488E9   89.488E9   68.863E9   48.272E9   3622.1    3622.1   0.
---------------------- TOWER FORE-AFT MODE SHAPES ----------------------------------
   0.8689   TwFAM1Sh(2) - Mode 1, coefficient of x^2 term
   0.2205   TwFAM1Sh(3) -       , coefficient of x^3 term
  -0.0908   TwFAM1Sh(4) -       , coefficient of x^4 term
   0.1167   TwFAM1Sh(5) -       , coefficient of x^5 term
  -0.1154   TwFAM1Sh(6) -       , coefficient of x^6 term
  42.5859   TwFAM2Sh(2) - Mode 2, coefficient of x^2 term
 -18.6419   TwFAM2Sh(3) -       , coefficient of x^3 term
 -20.3570   TwFAM2Sh(4) -       , coefficient of x^4 term
 -23.2686   TwFAM2Sh(5) -       , coefficient of x^5 term
```

```
------- ELASTODYN V1.00.* TOWER INPUT FILE ----------------------------
NREL 5.0 MW offshore baseline tower input properties for the (
---------------------- TOWER PARAMETERS -------------------------------
        11   NTwInpSt    - Number of input stations to speci
         1   TwrFADmp(1) - Tower 1st fore-aft mode structural
         1   TwrFADmp(2) - Tower 2nd fore-aft mode structural
         1   TwrSSDmp(1) - Tower 1st side-to-side mode struct
         1   TwrSSDmp(2) - Tower 2nd side-to-side mode struct
---------------------- TOWER ADJUSTMUNT FACTORS -----------------------
         1   FAStTunr(1) - Tower fore-aft modal stiffness tur
         1   FAStTunr(2) - Tower fore-aft modal stiffness tur
         1   SSStTunr(1) - Tower side-to-side stiffness tuner
         1   SSStTunr(2) - Tower side-to-side stiffness tuner
         1   AdjTwMa     - Factor to adjust tower mass densit
         1   AdjFASt     - Factor to adjust tower fore-aft st
         1   AdjSSSt     - Factor to adjust tower side-to-sic
---------------------- DISTRIBUTED TOWER PROPERTIES -------------------
  HtFract         TMassDen        TwFAStif        TwSSStif
    (-)             (kg/m)          (Nm^2)          (Nm^2)
0.0000000E+000  4.6670000E+003  6.0390300E+011  6.0390300E+011
1.0000000E-001  4.3452800E+003  5.1764400E+011  5.1764400E+011
2.0000000E-001  4.0347600E+003  4.4092500E+011  4.4092500E+011
3.0000000E-001  3.7354400E+003  3.7302200E+011  3.7302200E+011
4.0000000E-001  3.4473200E+003  3.1323600E+011  3.1323600E+011
5.0000000E-001  3.1704000E+003  2.6089700E+011  2.6089700E+011
6.0000000E-001  2.9046900E+003  2.1536500E+011  2.1536500E+011
7.0000000E-001  2.6501800E+003  1.7602800E+011  1.7602800E+011
8.0000000E-001  2.4068800E+003  1.4230100E+011  1.4230100E+011
9.0000000E-001  2.1747700E+003  1.1363000E+011  1.1363000E+011
1.0000000E+000  1.9538700E+003  8.9488000E+010  8.9488000E+01(
---------------------- TOWER FORE-AFT MODE SHAPES ---------------------
     1.1533  TwFAM1Sh(2) - Mode 1, coefficient of x^2 term
    -0.8622  TwFAM1Sh(3) -       , coefficient of x^3 term
     1.8042  TwFAM1Sh(4) -       , coefficient of x^4 term
    -1.5035  TwFAM1Sh(5) -       , coefficient of x^5 term
     0.4082  TwFAM1Sh(6) -       , coefficient of x^6 term
    19.1169  TwFAM2Sh(2) - Mode 2, coefficient of x^2 term
    -6.8956  TwFAM2Sh(3) -       , coefficient of x^3 term
     -8.185  TwFAM2Sh(4) -       , coefficient of x^4 term
    -5.1085  TwFAM2Sh(5) -       , coefficient of x^5 term
```

Fig. 5: Tower property file of FAST v7 (left side) and OpenFAST (right side)

For the NREL 5MW DeepCwind model, the other settings are as same as the Hywind model. It is noted that the wave conditions are defined in AQWA's input and wind condition is defined in AeroDyn input file. In the AeroDyn input file, the directory of the wind field is specified as shown in Fig. 6. The file with an extension of .wnd is the Bladed-style wind speed data file that can be generated by TurbSim. It is noted the .sum file must be put in the same directory when a .wnd file is used. It is suggested to use .bts file that has complete same wind data as the .wnd file.

```
NREL 5.0 MW offshore baseline aerodynamic input properties; Compatible with AeroDyn v12.58.
SI            SysUnits    - System of units for used for input and output [must be SI for FAST] (unquoted string)
STEADY       StallMod    - Dynamic stall included [BEDDOES or STEADY] (unquoted string)
USE_CM        UseCm       - Use aerodynamic pitching moment model? [USE_CM or NO_CM] (unquoted string)
EQUIL         InfModel    - Inflow model [DYNIN or EQUIL] (unquoted string)
SWIRL         IndModel    - Induction-factor model [NONE or WAKE or SWIRL] (unquoted string)
   0.005      AToler      - Induction-factor tolerance (convergence criteria) (-)
PRANDtl       TLModel     - Tip-loss model (EQUIL only) [PRANDtl, GTECH, or NONE] (unquoted string)
PRANDtl       HLModel     - Hub-loss model (EQUIL only) [PRANDtl or NONE] (unquoted string)
"WindData\NREL5MW_14.wnd"                                 WindFile     - Name of file containing wind data (quoted string)
   90.0       HH          - Wind reference (hub) height [TowerHt+Twr2Shft+OverHang*SIN(ShftTilt)] (m)
   0.0        TwrShad     - Tower-shadow velocity deficit (-)
9999.9        ShadHWid    - Tower-shadow half width (m)
9999.9        T_Shad_Refpt - Tower-shadow reference point (m)
   1.225      AirDens     - Air density (kg/m^3)
   1.464E-5   KinVisc     - Kinematic air viscosity [CURRENTLY IGNORED] (m^2/sec)
   0.02479    DTAero      - Time interval for aerodynamic calculations (sec)
   8          NumFoil     - Number of airfoil files (-)
"AeroData\Cylinder1.dat"                            FoilNm      - Names of the airfoil files [NumFoil lines] (quoted strings)
"AeroData\Cylinder2.dat"
"AeroData\DU40_A17.dat"
"AeroData\DU35_A17.dat"
"AeroData\DU30_A17.dat"
"AeroData\DU25_A17.dat"
"AeroData\DU21_A17.dat"
"AeroData\NACA64_A17.dat"
  17          BldNodes    - Number of blade nodes used for analysis (-)
```

Fig. 6: AeroDyn input

4. Model the platform in AQWA

After getting the FAST model prepared, the next stage is to model the platform in AQWA. First, we need to build the 3D geometry of the DeepCwind model using a CAD tool. Please note only the three large columns and the middle column are modeled as shown in Fig. 7. The slender bodies are ignored at this stage since they will be modelled as Morison elements in AQWA. Please note that the upper part and lower part must be combined as one structure using Boolean operation. Save the structure as a parasolid type file (with an extension of x_t).

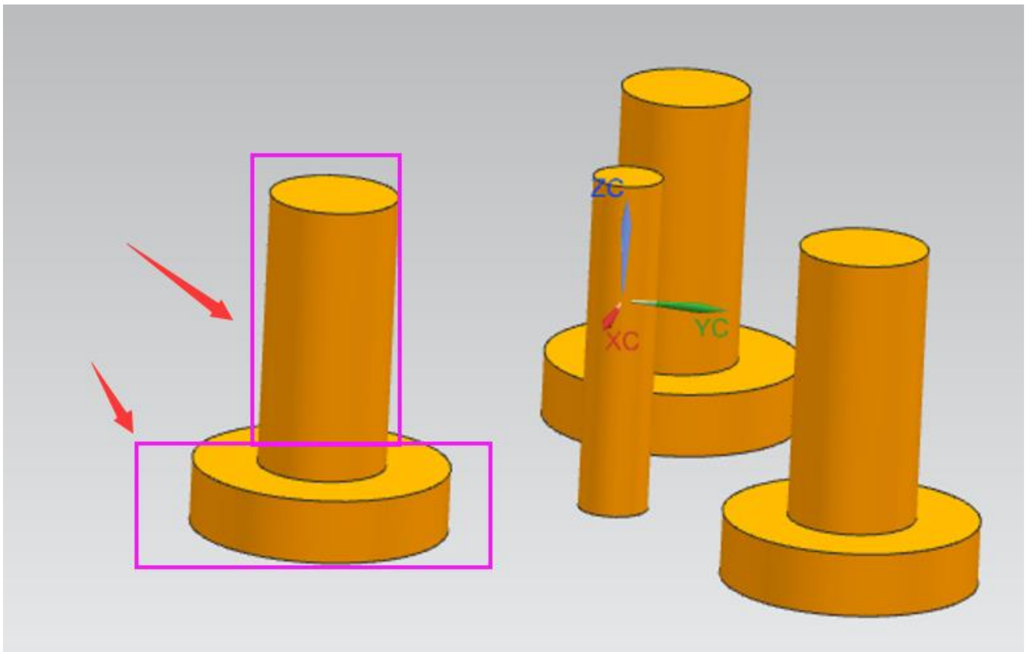


Fig. 7: Large diameter columns of the DeepCwind model

Open ANSYS-Workbench, create a “Geometry” task by drag “Geometry” element in the left component system to the white blank space in the right side.

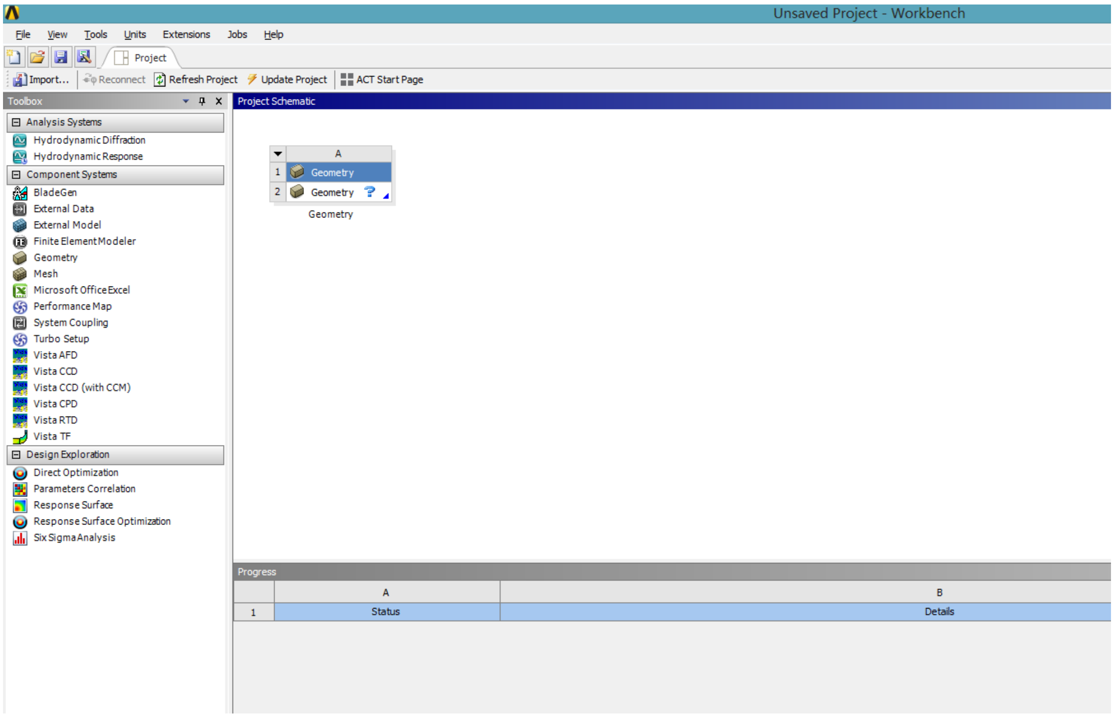


Fig. 8: ANSYS-Workbench

Set preference of geometry edit tool to DesignModeler, Tools→Geometry Import→Preferred Geometry Editor, → select “DesignModeler” →click OK. Save the project.

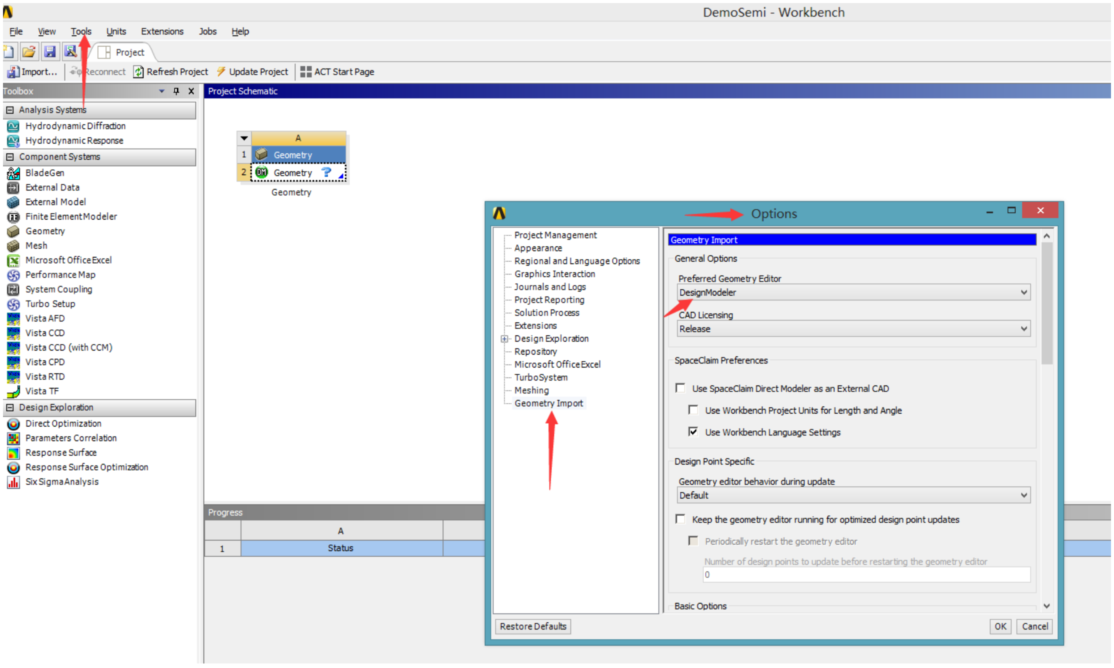


Fig. 9: Setting preference of geometry editor

Double click “Geometry” with a “?”, or right click on it and select “DesignModeler”, to open geometry edit window as shown below.

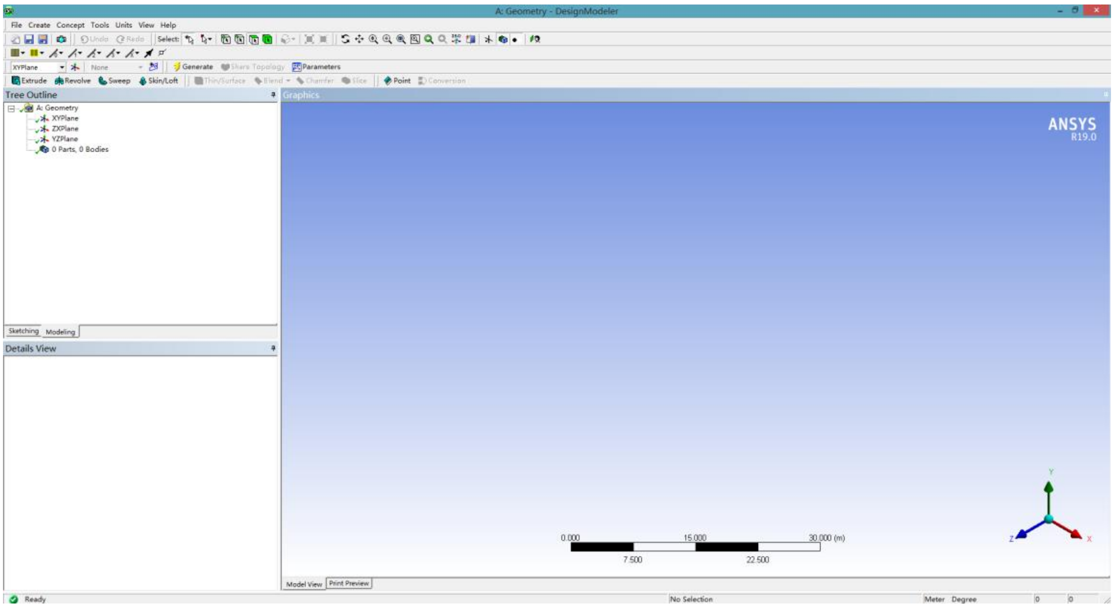


Fig. 10: Geometry edit window

Import geometry by clicking: File→Import external geometry, select the saved 3D model (i.e. the *.x_t file)exported from CAD tool, as shown below.

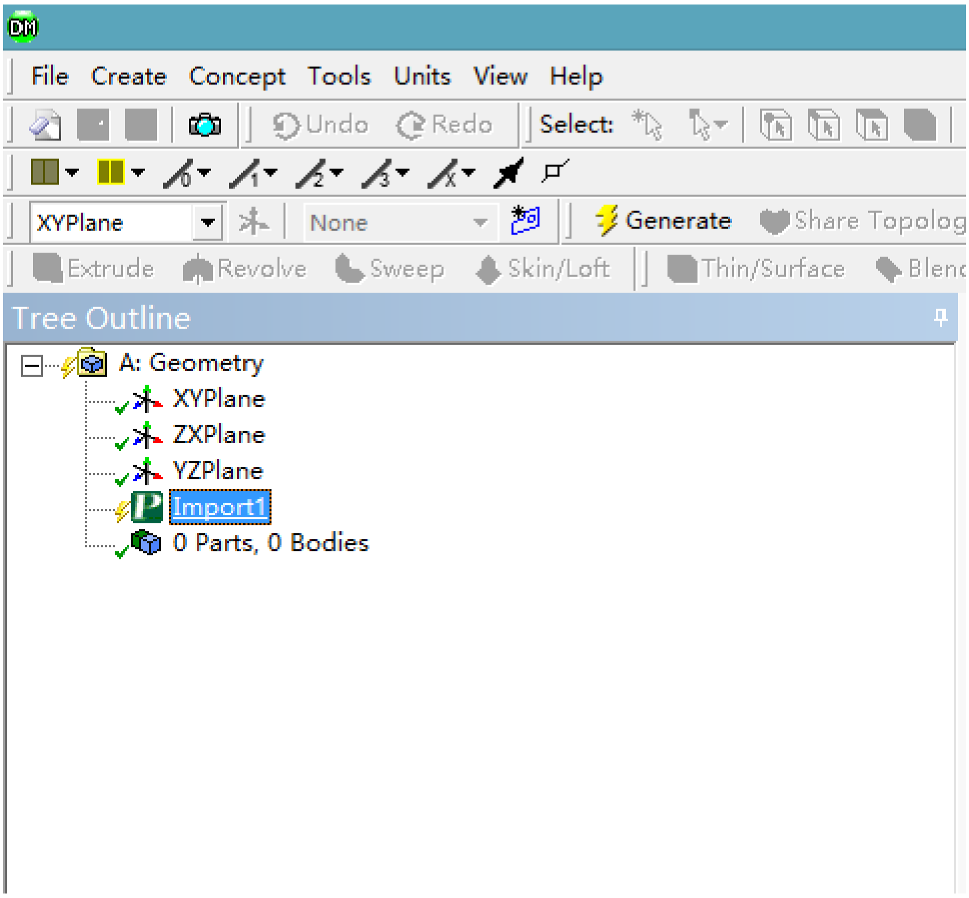
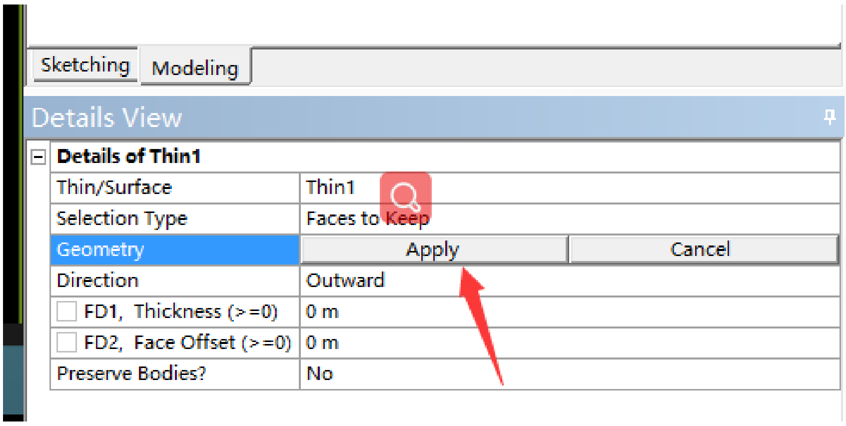


Fig. 11: Import geometry.

Right click on “Import1” and select “Generate”. The model will be generated. Click the Thin/Surface, press <Ctrl> and hold, select all surfaces and click apply. Select “Face to keep” for “Selection Type”, “Outward” for “Direction”, and other options as shown below.

(a) Thin



(b) Apply thin

Fig. (12): Thin the surface of the platform model

Then, right click on “Thin1” in the left side and select generate. The panel model is built.

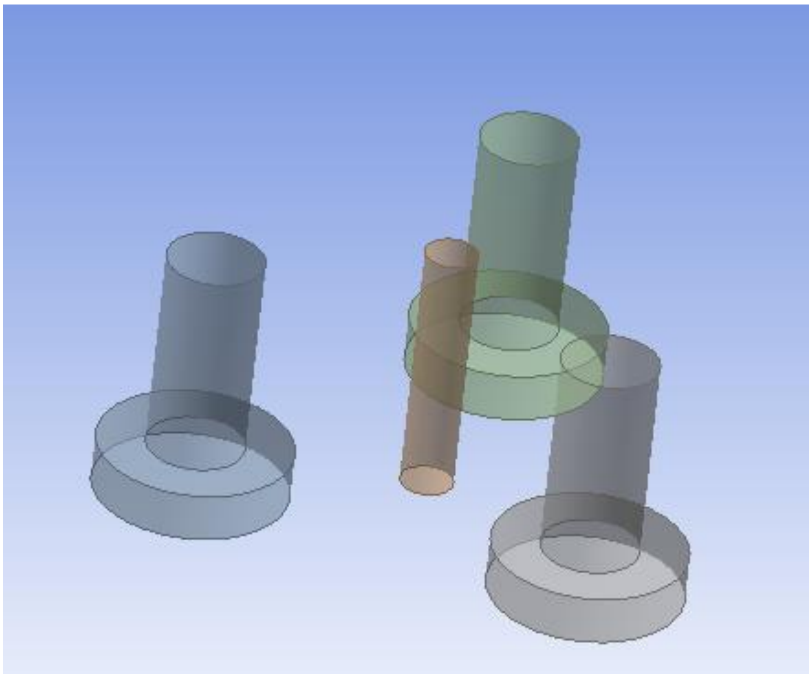


Fig. 14: Panel model of the platform

Then, we need import the points of the slender bodies. The coordinates of the sleder bodies are presented in Table 3-2 in the OC4 model definition document (downloaded via the link given in Section 2), as shown in Fig. 15. We need copy the coordinates of these nodes to a text file and reformat the data to a specific format that can be accepted by DesignModeler as shown in Fig. 16. In Fig. 16, the first column is the group ID. The 2nd column is the point id. The next three columns are the x,y,z coordinates of the point.

Table 3-2: Member Geometry

Column Name	Abbr.	Start location (X,Y,Z)	End location (X,Y,Z)	Length (m)	Wall Thick. (m)
Main Column	MC	(0, 0,-20)	(0, 0,10)	30	0.03
Upper Column 1	UC1	(14.43, 25, -14)	(14.43, 25, 12)	26	0.06
Upper Column 2	UC2	(-28.87, 0, -14)	(-28.87, 0, 12)	26	0.06
Upper Column 3	UC3	(14.43, -25, -14)	(14.43, -25, 12)	26	0.06
Base Column 1	BC1	(14.43, 25, -20)	(14.43, 25, -14)	6	0.06
Base Column 2	BC2	(-28.87, 0, -20)	(-28.87, 0, -14)	6	0.06
Base Column 3	BC3	(14.43, -25, -20)	(14.43, -25, -14)	6	0.06
Delta Pontoon, Upper 1	DU1	(9.20, 22, 10)	(-23.67, 3, 10)	38	0.0175
Delta Pontoon, Upper 2	DU2	(-23.67, -3, 10)	(9.20, -22, 10)	38	0.0175
Delta Pontoon, Upper 3	DU3	(14.43, -19, 10)	(14.43, 19, 10)	38	0.0175
Delta Pontoon, Lower 1	DL1	(4, 19, -17)	(-18.47, 6, -17)	26	0.0175

Fig. 15: Coordinates of the nodes of the slender bodies

```
# Group 1
1	1	9.2	22	10
1	2	-23.67	-3	10
1	3	14.43	-19	10
1	4	4	19	-17
1	5	-18.47	-6	-17
1	6	14.43	-13	-17
1	7	1.625	2.815	10
1	8	-3.25	0	10
1	9	1.625	-2.815	10
1	10	1.625	2.815	-17
1	11	-3.25	0	-17
1	12	1.625	-2.815	-17
1	13	1.625	2.815	-16.2
```

Fig.16: Points definition

Import the points. Create→Point, define the options as shown below.

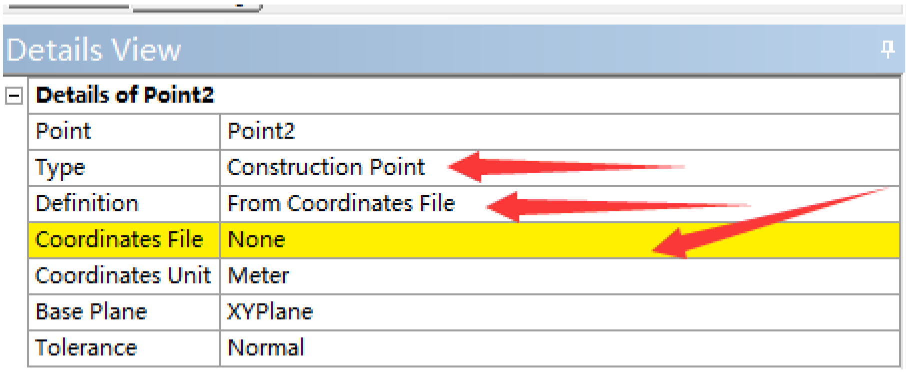


Fig. 17: Import the points

Select the coordinates file and then generate the point by press F5 or right clicking on Point1 and then selecting Generate.

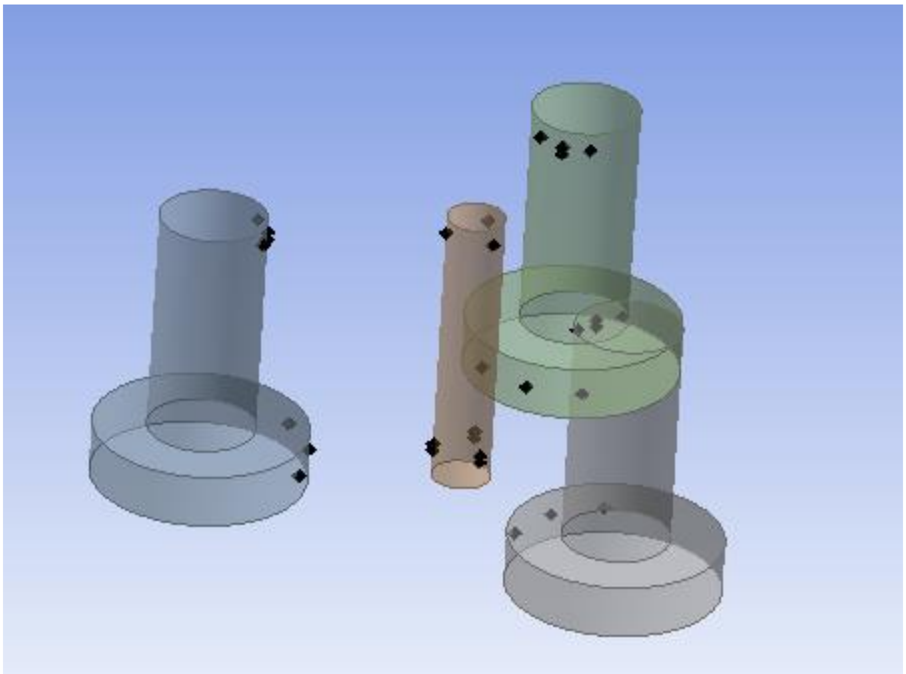


Fig. 18: Points imported

Then create lines. Concept→Lines from points, create every line body by click the corresponding two endpoints. Generate each line body and then the line bodies are modelled.

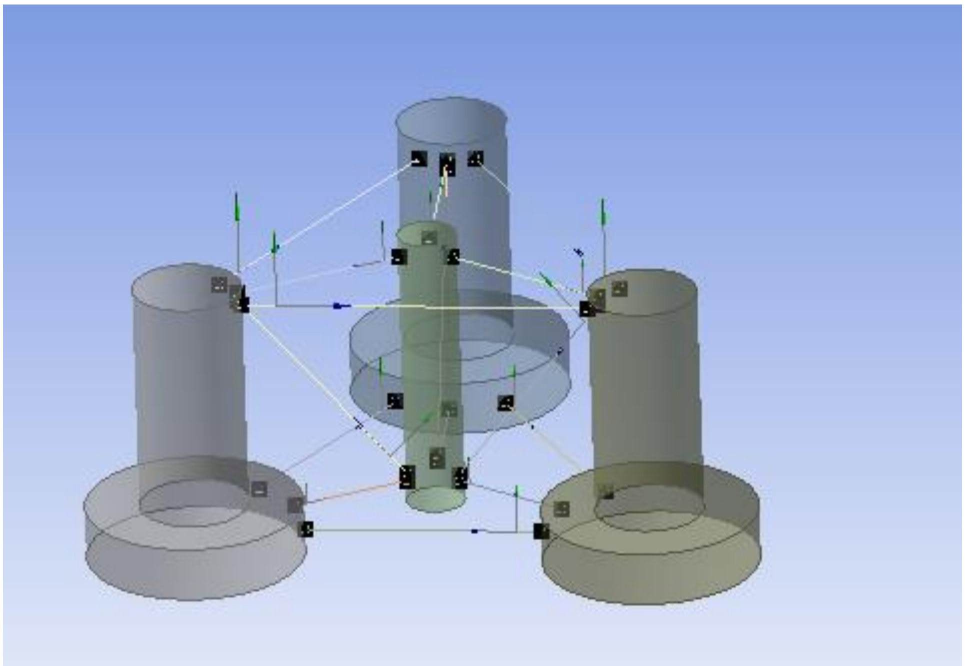
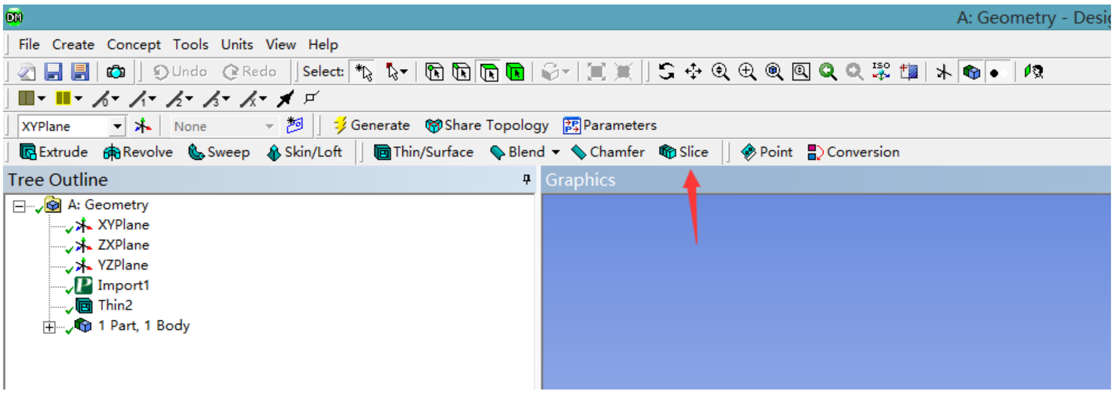
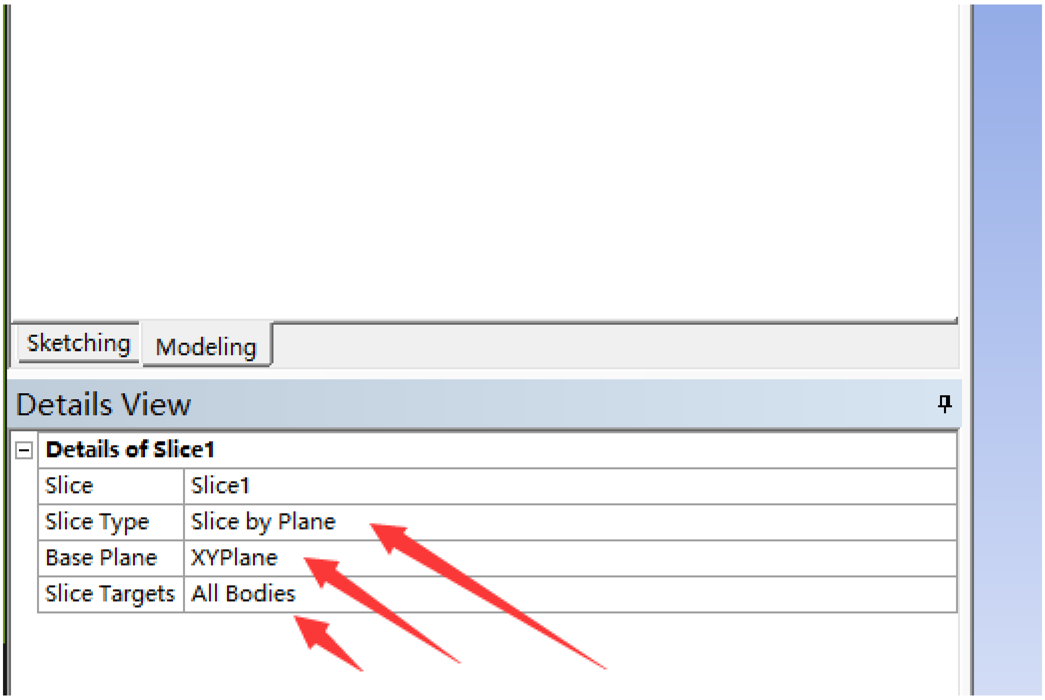


Fig. 19: Line bodies modelled

Then slice the panel model to create the wet surface. Slice, Select all the panel model, and set the options as follows to slice the panel model using XYPlane.



(a) Slice task



(b) Slice option

Fig. 20: Slice operation

Select all the part and right click and form them to a new part, save and exit DM

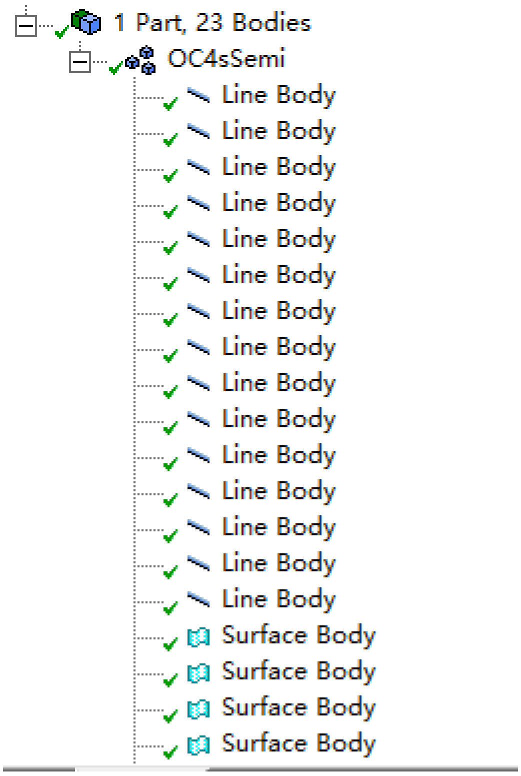


Fig. 21: Form to a new part

5. Hydrodynamic modeling

In Workbench, drag “Hydrodynamic diffraction” on geometry to create a frequency domain analysis task. Drag “Hydrodynamic response” on solution of the Hydrodynamic diffraction” task to create a new time domain analysis task.

Open “Diffraction” model by double click “Model” or “Setup”

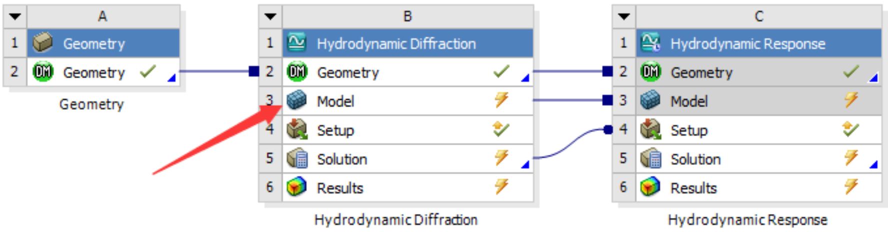


Fig. 22: Hydrodynamic modeling tasks

Click on geometry, set water depth and water size.

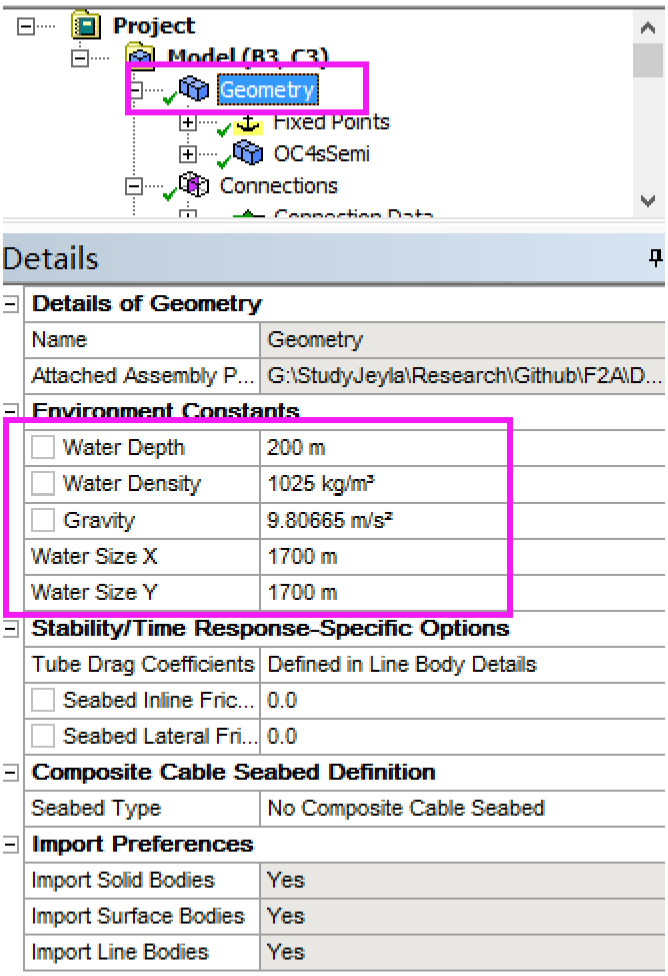
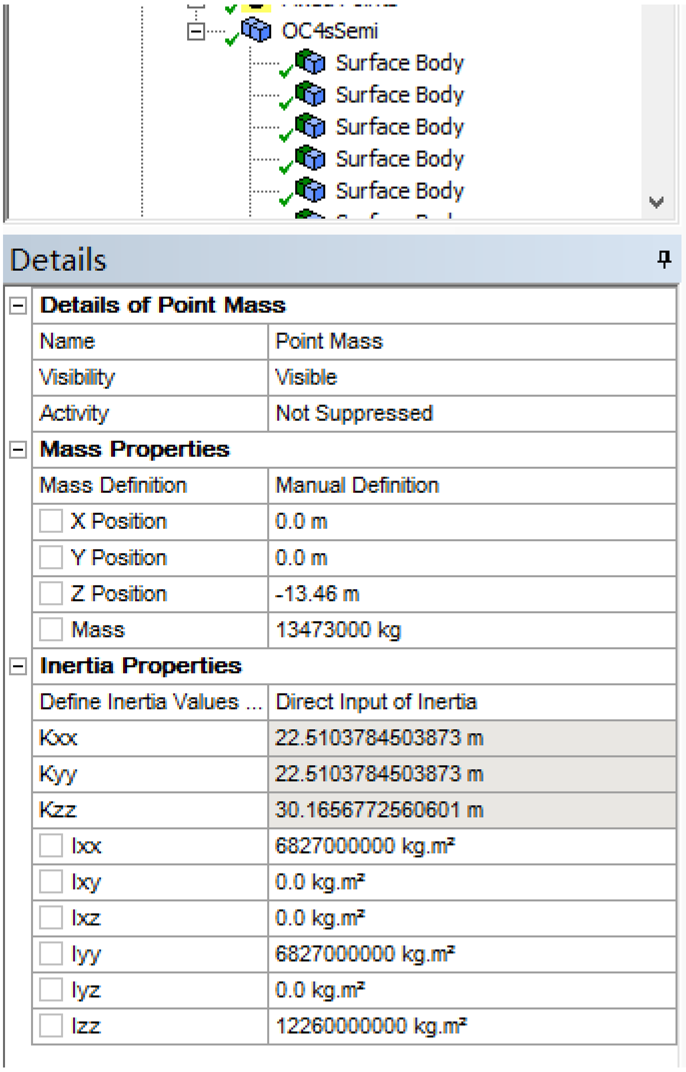


Fig. 23: Water size and water depth

Right click “OC4Semi”, add point mass and set the CoG, and the inertial property of the platform as shown below.



Details of Point Mass	
Name	Point Mass
Visibility	Visible
Activity	Not Suppressed
Mass Properties	
Mass Definition	Manual Definition
X Position	0.0 m
Y Position	0.0 m
Z Position	-13.46 m
Mass	13473000 kg
Inertia Properties	
Define Inertia Values ...	Direct Input of Inertia
Kxx	22.5103784503873 m
Kyy	22.5103784503873 m
Kzz	30.1656772560601 m
Ixx	6827000000 kg.m²
Ixy	0.0 kg.m²
Ixz	0.0 kg.m²
Iyy	6827000000 kg.m²
Iyz	0.0 kg.m²
Izz	12260000000 kg.m²

Fig. 24: Mass information

Set the property of each line body, including their diameter, Ca, Cd. As the mass of the slender bodies has been included in the point mass of the panel model. Therefore, here we need set a very small density for the line body material.

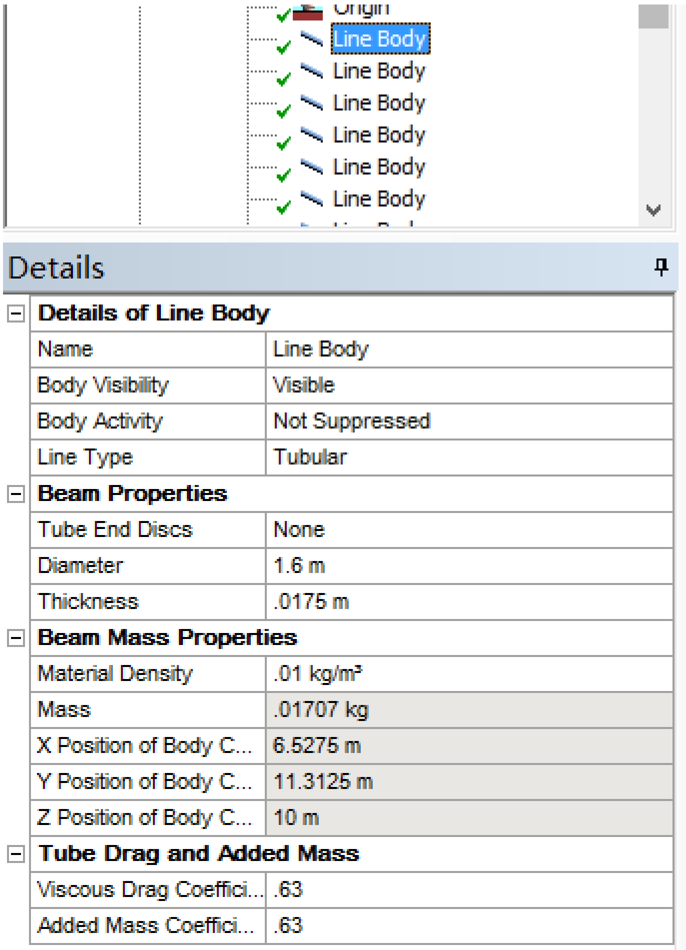


Fig. 25: Line body property

Right click “OC4Semi”, add additional damping, set the damping values. If the unit is not N/(rad/s), you can set the units in the top menu.

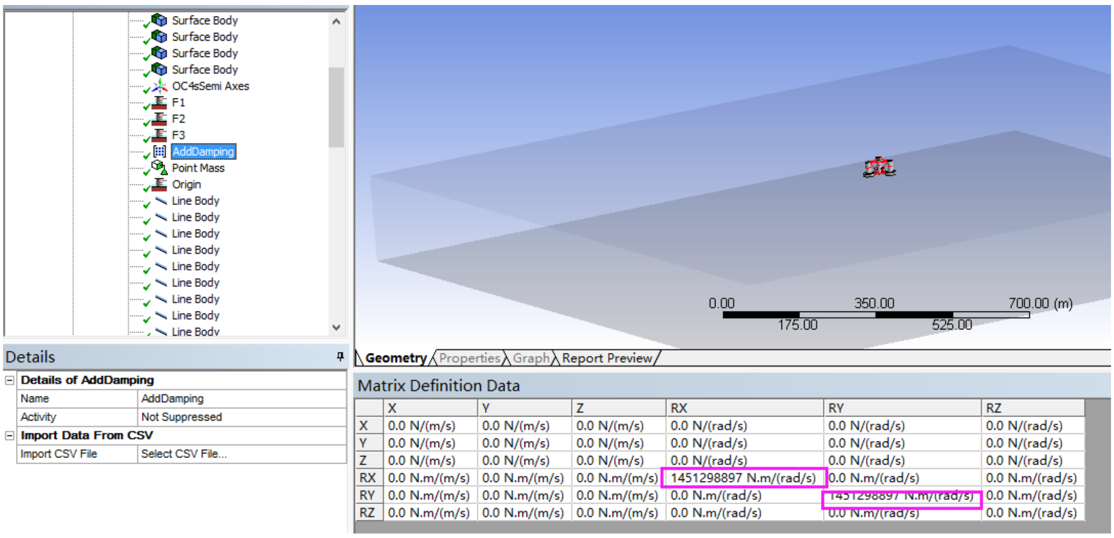


Fig. 26: Additional damping

Generate mesh. For this semisub model, the mesh is very simple to generate. We need specify a mesh size for the Morison element. Right click Mesh, Insert Mesh Control, Sizing, select all the line bodies in the right side (press Ctrl and hold on), and apply. Set the mesh size, 1 m is suggested. Then, set the overall size of the panel model. The basic control type is sufficient. Set the maximum size and tolerance, 2 m and 0.1 m are suggested for this model. Then, right click Mesh and generate.

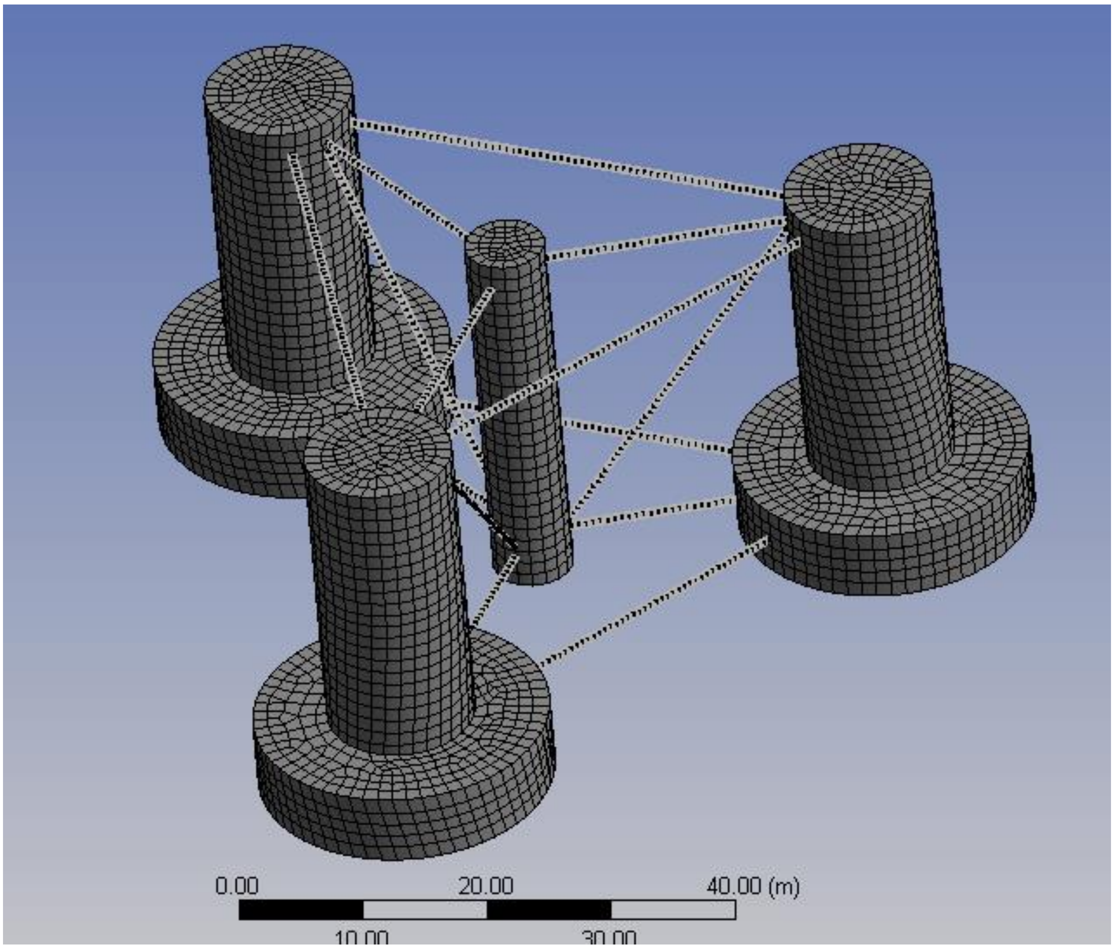


Fig. 27: generated mesh

Click Analysis settings of B4 (Hydrodynamic diffraction). Select Yes for ignore modeling rule violations. I suggest to select yes for “Calculate extreme low/high frequencies” and “ASCII hydrodynamic database”.

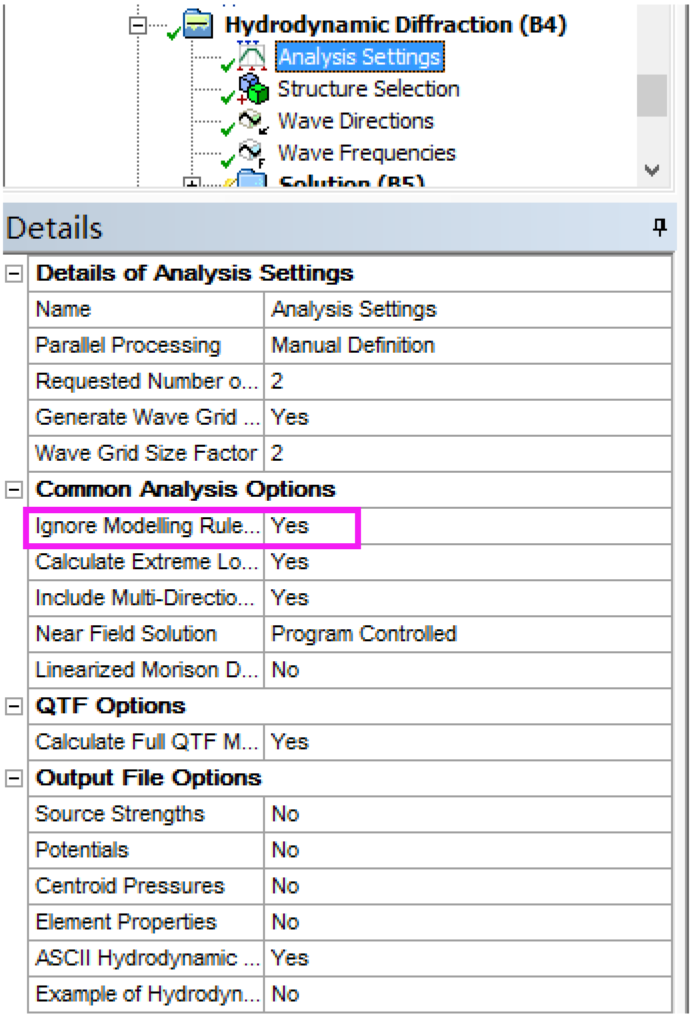


Fig. 28: Settings of frequency domain analysis

Set wave headings and frequencies as shown below.

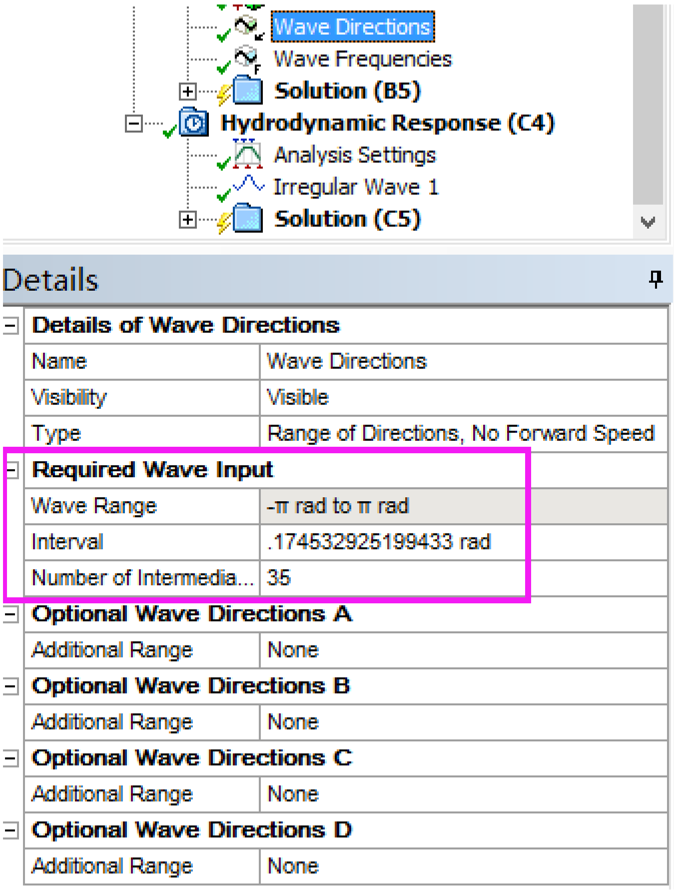


Fig. 29: Wave direction setting

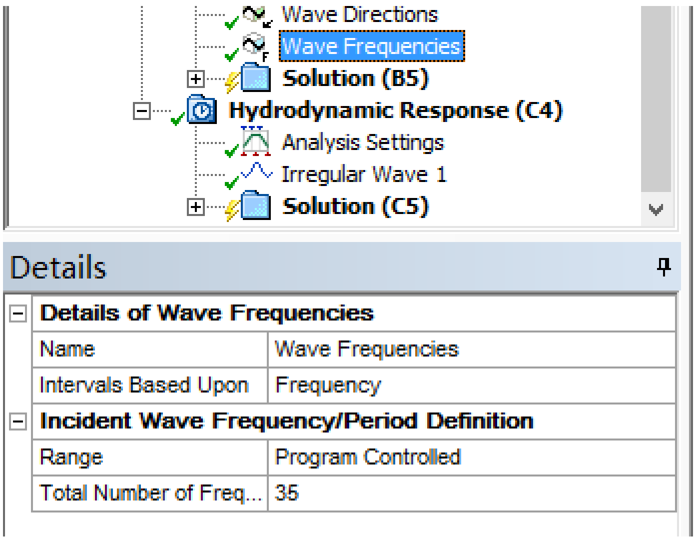


Fig. 30: Frequency settings

Right click B4 and solve. When the simulation terminates normally, the ANALYSIS.HYD (binary type) and ANALYSIS.AH1 (ASCII type) will be generated in the corresponding directory. These two files contain the hydrodynamic data including added mass, hydrostatic stiffness, radiation damping and excitation force. The data saved in the HYD file will be used for time domain analysis. You are suggested to copy the HYD file to another folder for running F2A.

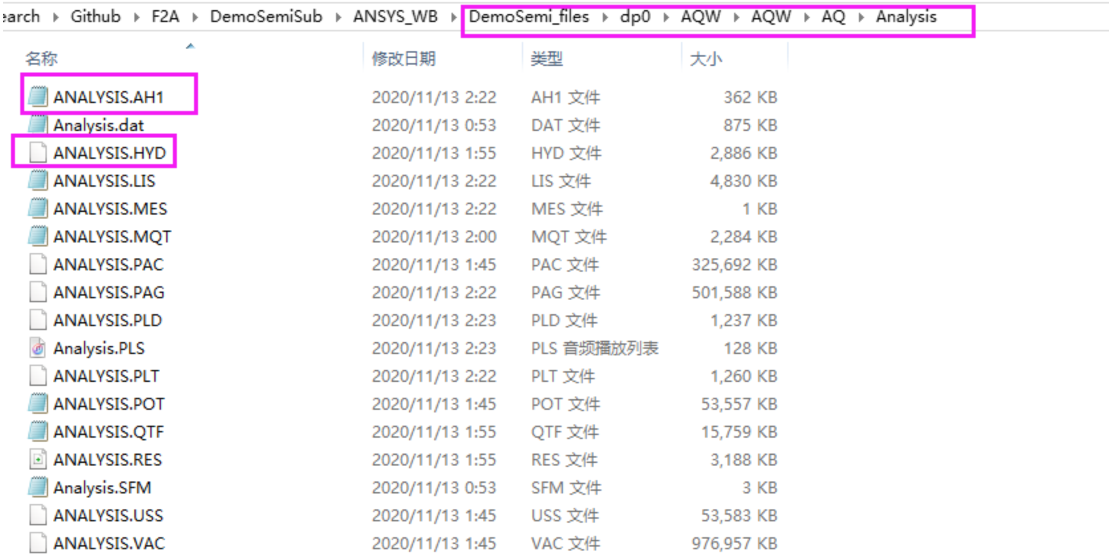


Fig. 31: Generated files in frequency domain analysis

Then, we need to perform an initial time domain analysis. First, we need to define the fairleads and anchors. Fairlead is defined by adding connection points on the structure. Anchors are defined by added fixed points.

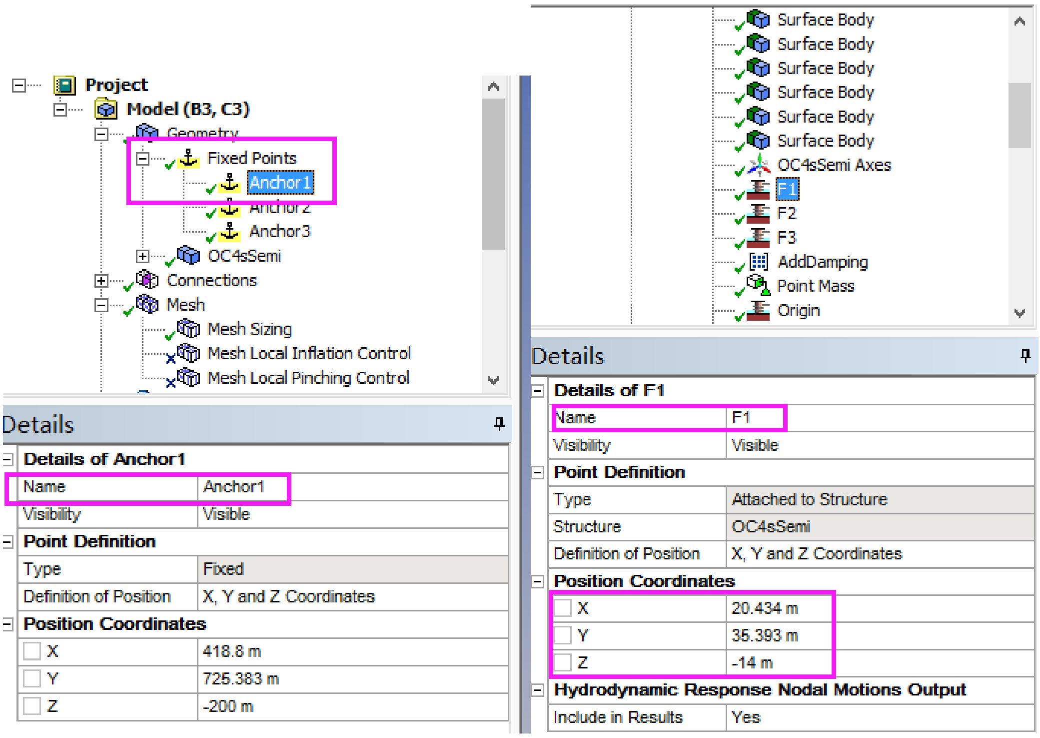


Fig. 32: Fairleads and anchors

Define moorings. Inset a catenary section under the Connection Data tree. Define the mooring properties. Note that the mass density is the mooring density in air.

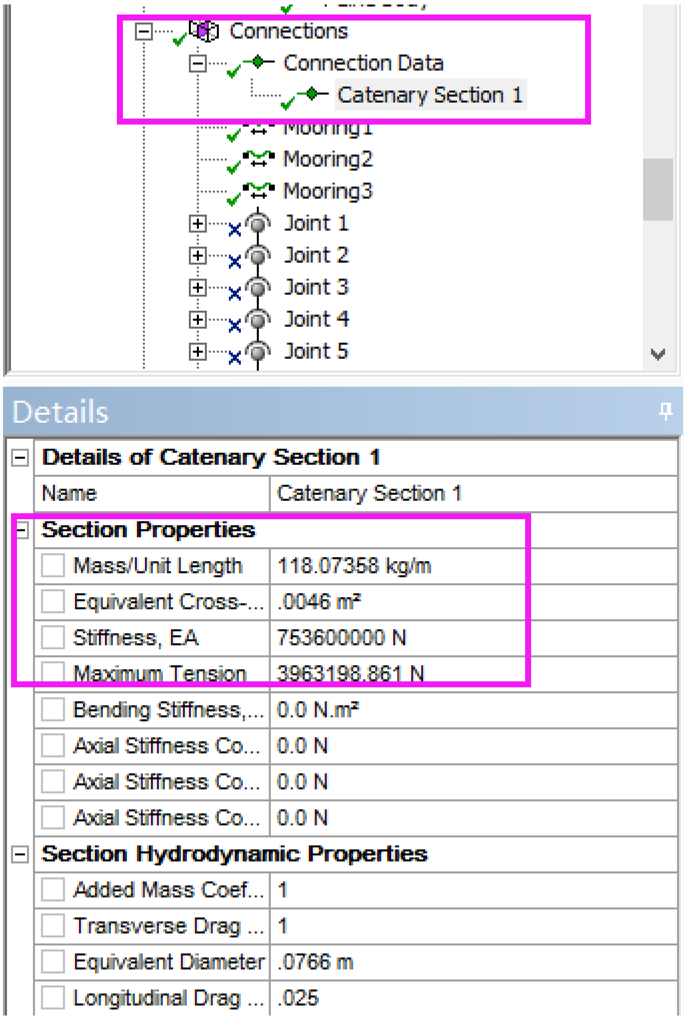


Fig. 33: Mooring section

Insert Connection→Cable, set cable type and connectivity, mooring length and other property as shown below. dZ means the possible movement of the platform in the heave direction. Set all the mooring lines following the same steps.

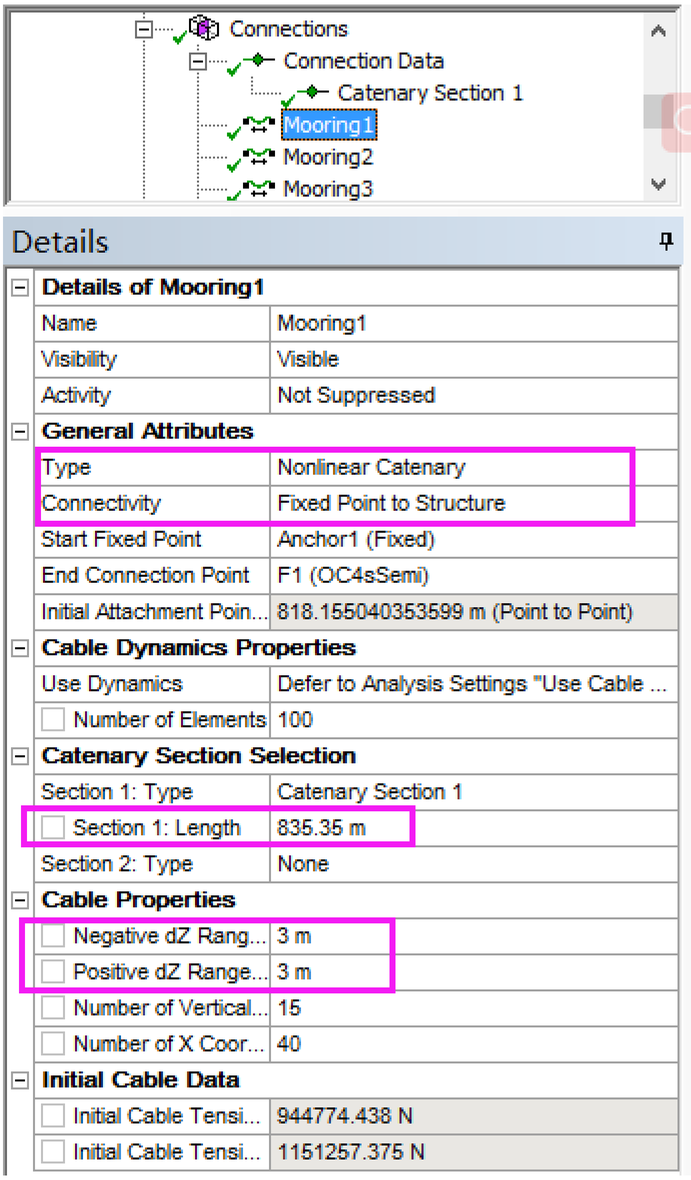


Fig. 34: Mooing lines

Set time domain analysis by clicking Analysis Settings of C4. Define “computation type” and “Time response specific options”; note that the “Call Routine user_force” is set to “No” since we here are using Workbench as a preprocessor to generate the input of a time domain analysis.

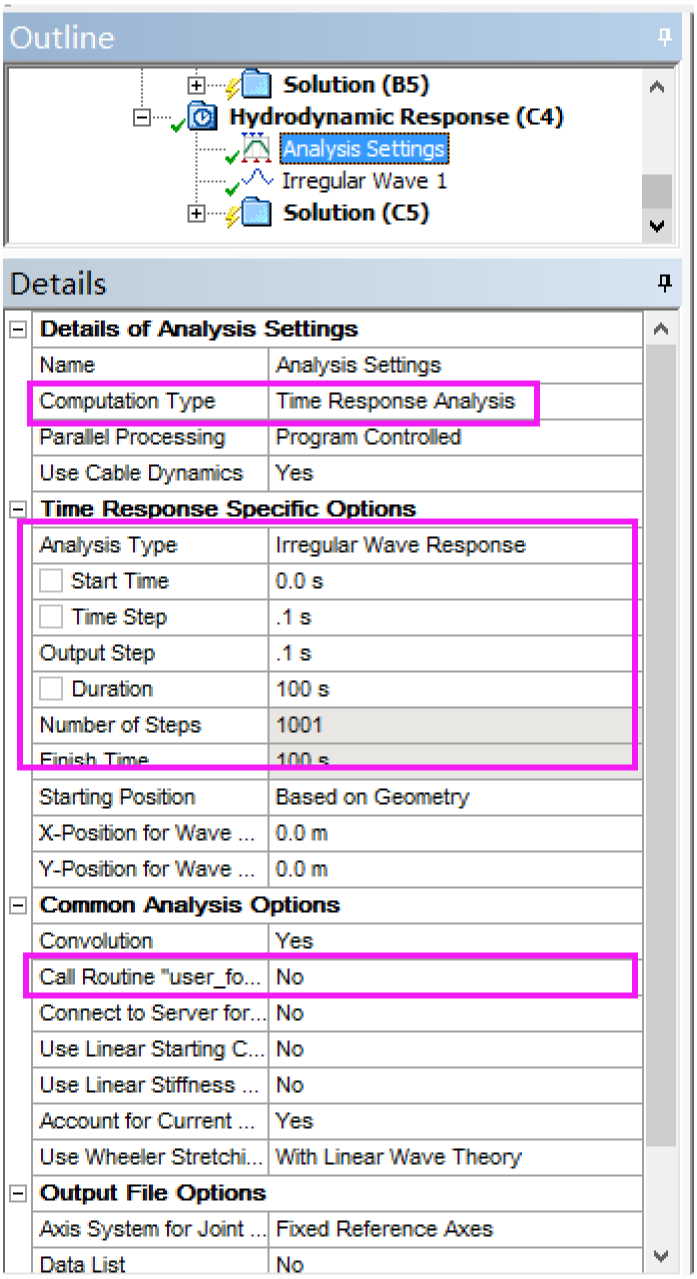


Fig. 35: Time domain analysis settings

Set wave condition. Right click C4, insert an irregular wave. Set “Wave type”, significant wave height and peak spectral period, and etc.

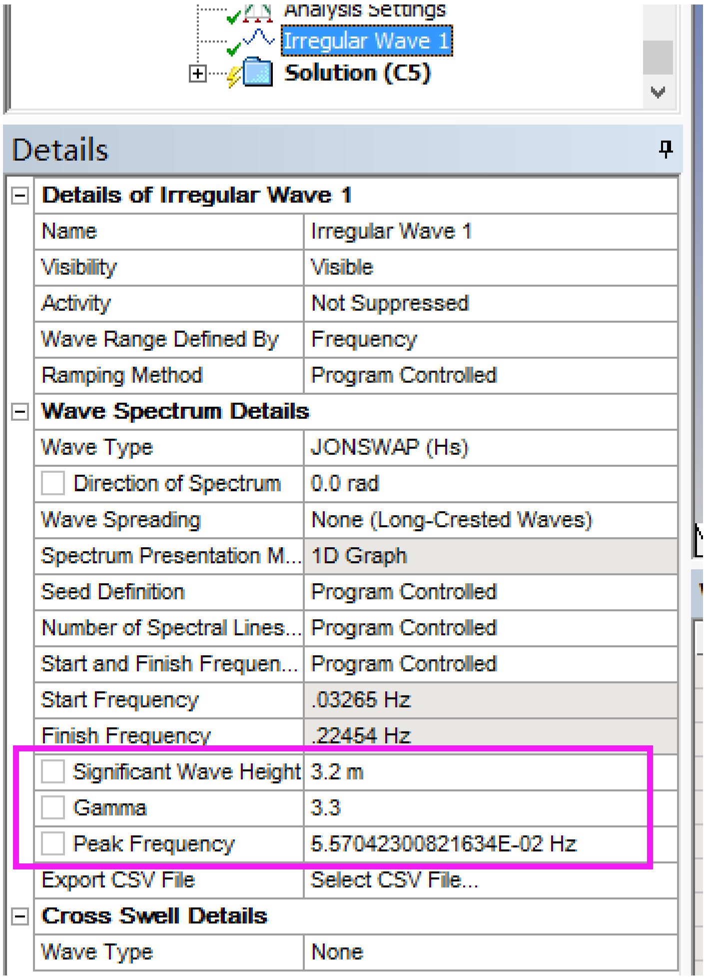


Fig. 36: Wave condition

Right click C4 and solve. ANSYS-Workbench will generate a time response input in the relevant directory. Copy the TimeResponse.dat to another directory.

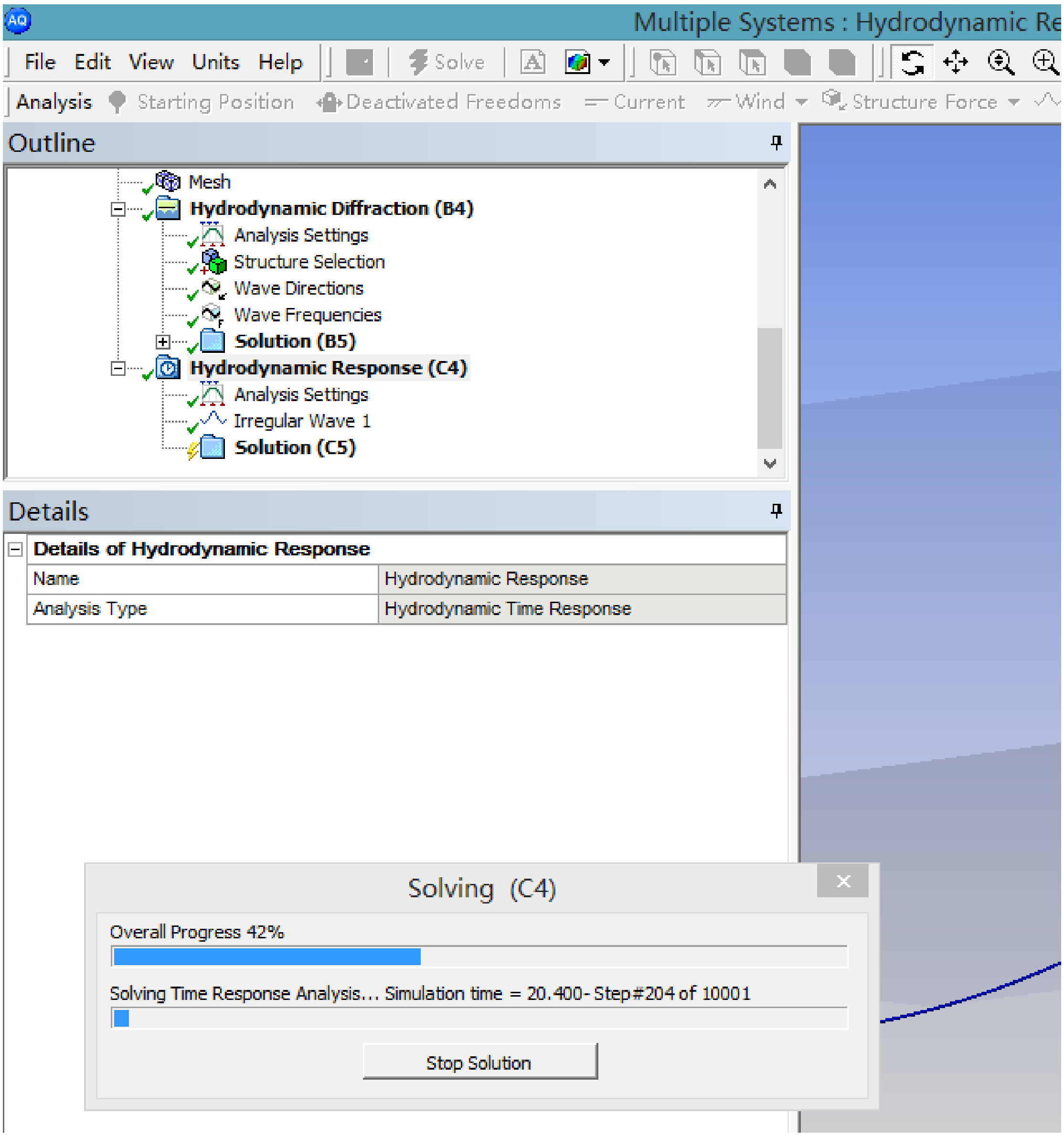


Fig. 37: Running time domain analysis

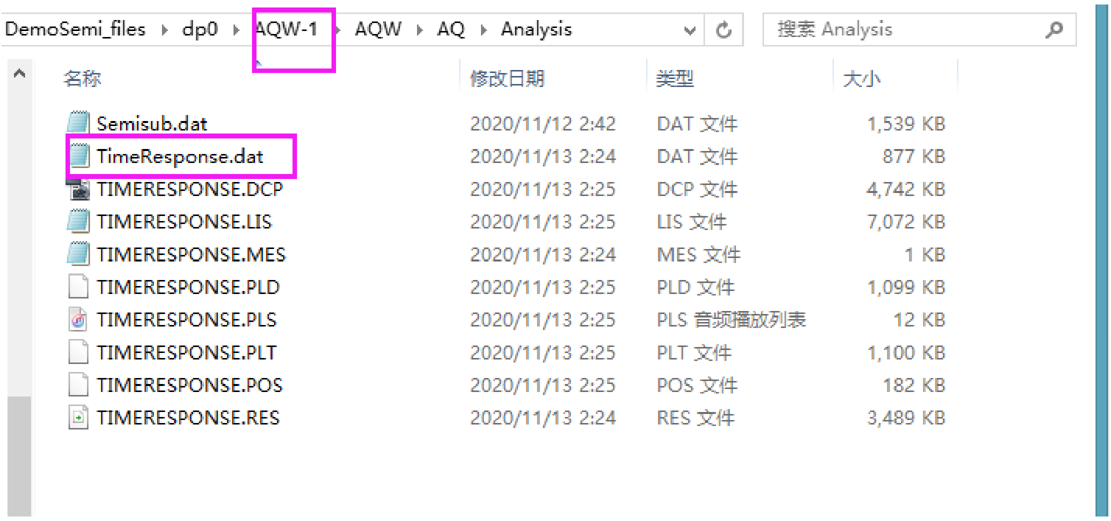


Fig. 38: Time response files generated by Workbench

Put the HYD file generated from the frequency domain analysis to a separated folder but this is not mandatory. It is just for a clean presentation of the root directory.

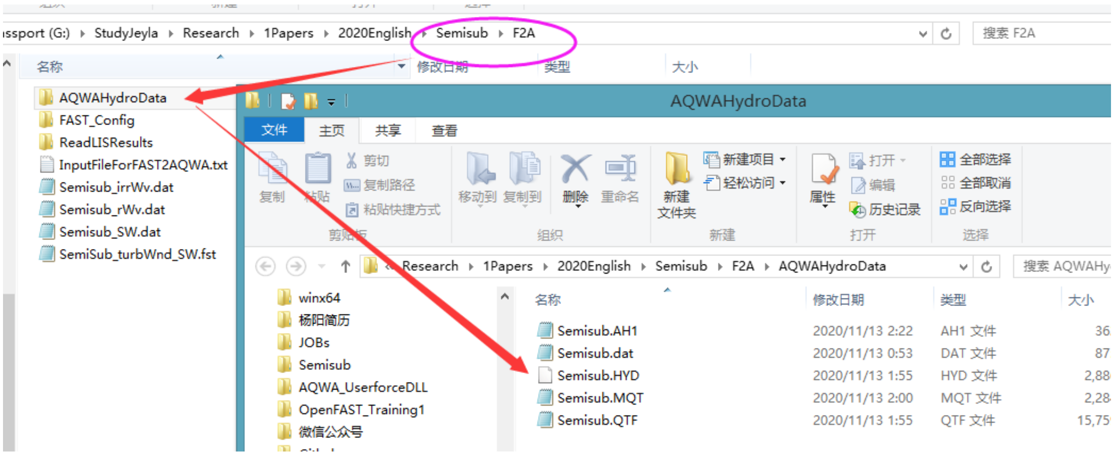


Fig. 39: Hydrodynamic data directory

Open Semisub_irrWv.dat and add “FDLL” option to activate the Call Routine for user_force.

```
*********1*********2*********3*********4*********5*********6*********7*********8
*23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
********************************************************************************
******************* File generated by Aqwa in Workbench 19.0 *******************
********************************************************************************
* Project Title                     :
* Project Reference                 :
* Project Author                    :
* Project Description               :
* Date of Creation                  : 2020/11/10 23:46:18
* Last Modified                     : 2020/11/12 11:35:13
* This analysis file written at     : 2020/11/12 18:24:06
* Hydrodynamic Solver Unit System : Metric: kg, m [N]
********************************************************************************
*********************************** DECK  0 ************************************
********************************************************************************
JOB AQWA  NAUT  IRRE
TITLE
NUM_CORES          1
OPTIONS CONV FDLL NASF
OPTIONS NODL NOST
OPTIONS WHLS REST END
RESTART  1  5
********************************************************************************
*********************************** DECK  1 ************************************
********************************************************************************
          COOR
```

Fig. 40: Input of time domain analysis with “FDLL”

In DECK 13, you can modify the wave condition by changing relevant parameters.

```
          NONE
*********************************** DECK 13 ************************************
********************************************************************************
          SPEC
      HRTZ
      NAME            Irregular Wave 1
      WRMP
      SPDN                    0.
      SEED            0
      NSPL           50
      JONH                                       3.3       3.2 5.5704e-2
 END
********************************************************************************
*********************************** DECK 14 ************************************
********************************************************************************
```

Fig. 41: Wave condition definition in DECK 13

Open InputFileForFAST2AQWA.txt, define the primary input file of FAST. In addition, the ID of the structure in AQWA that connects to the tower directly. Typically this value is 1 if there is only one structure is modelled.

```
InputFileForFAST2AQWA.txt - 记事本
文件(F)  编辑(E)  格式(O)  查看(V)  帮助(H)
! Input file of the interface FAST2AQWA that is developed by Y.Yang (PDRA in LJMU) on 10-March-2020 for performing fully-coupled analysis of floating o
turbines (FOWTs)
! The FAST2AQWA is implemented through the user_force DLL. FAST v7 is used to examine the aero-elastic effects of the wind turbine.
! This file is specified for NREL 5MW wind turbine supported by the OC3-Hywind platform (Do not remove anyline below)
---------------- FAST Configuration -------------------
"SemiSub_turbWnd_SW.fst"          - Prifile         - Primary input file for FAST
True                      - CouplingFlag       - Flag of coupling interface. False: the platform motion and velocity imported to FAST WILL BE ZERO.
---------------- AQWA structure properties ------------
1                         - IndexTwrStr        - Index of the structure connecting to the tower directly.
True                      - OPtfmFrc           - Flag of whether output the platform forces
---------------- END OF THE INPUT --------------------
```

6. Run F2A

Copy user_force64.dll into the bin\Win64 folder of AQWA installation directory. You can back-up the original DLL before replacing it.

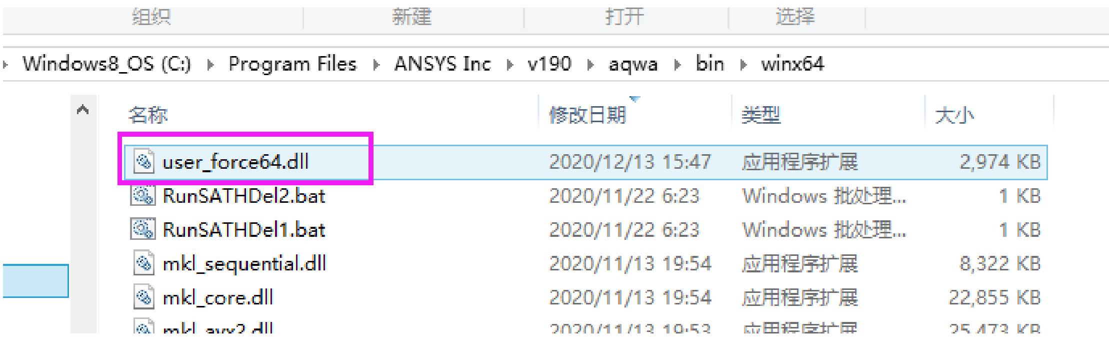


Fig. 43: user_force64.dll replacement

Press <Win> + R, type cmd and enter.

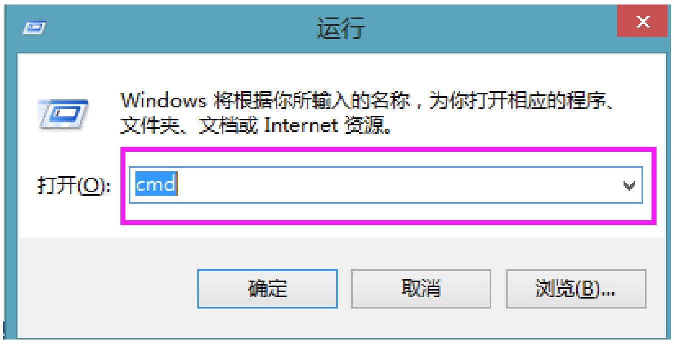


Fig.44: To open command window

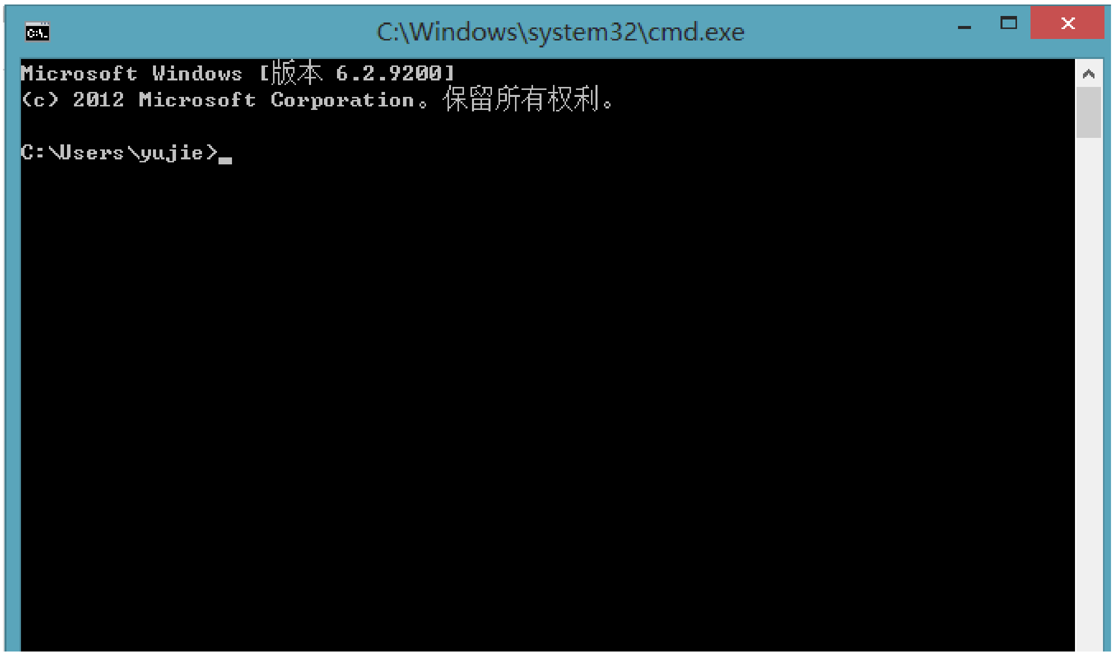


Fig. 45: Command window opened

Go the directory of bin\win64 of AQWA installation directory using the cd command,

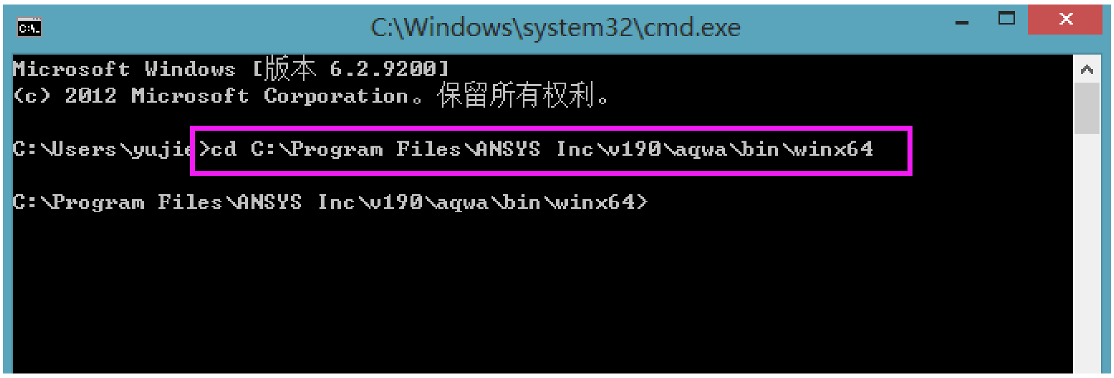


Fig. 46: Go to the AQWA directory

Run F2A, type the content within the quotes: “aqwa.exe /nowind <directory of timeResponse input>”. Here in my computer is shown below:

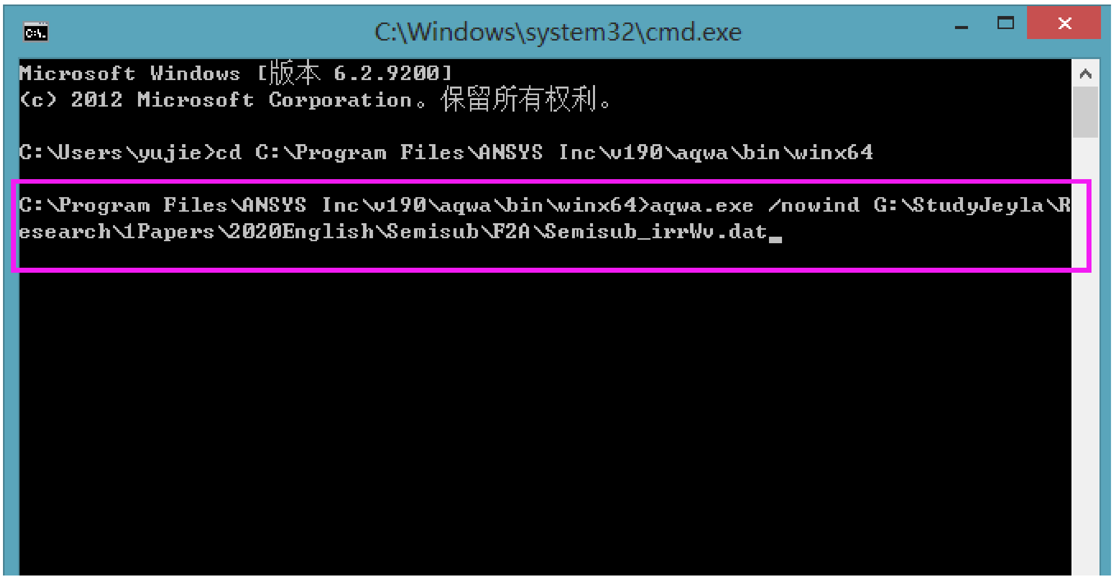


Fig. 47: Run F2A

Press enter, F2A will be running:

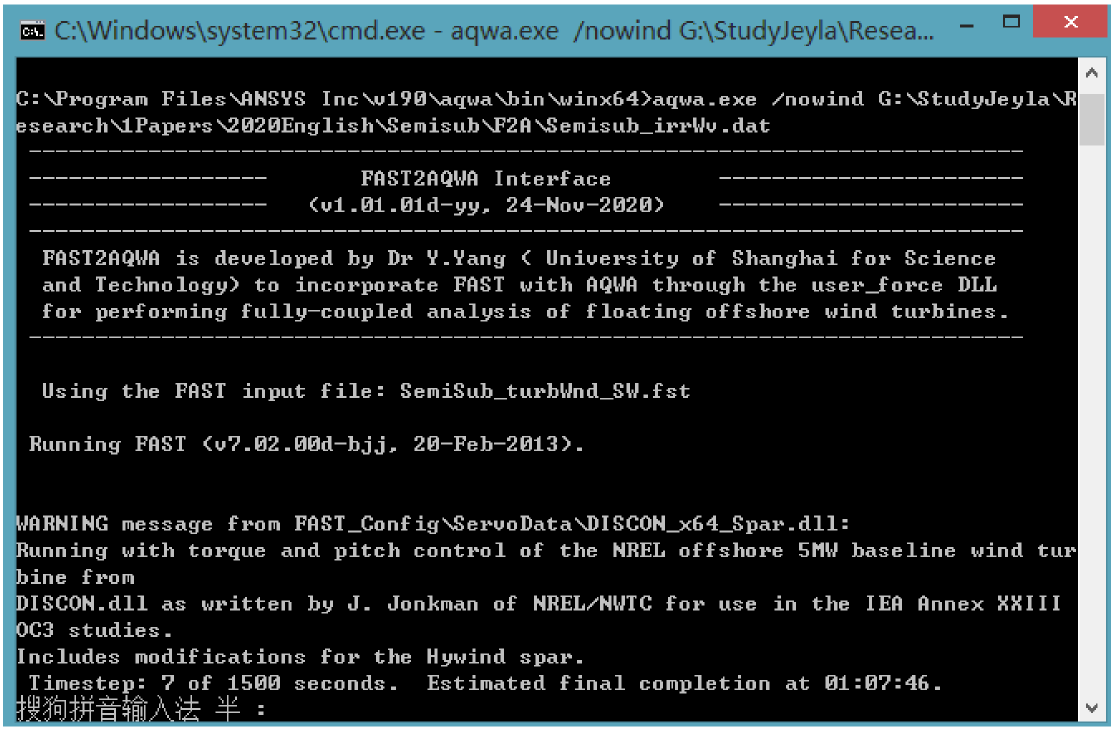


Fig. 48: Running F2A

7. Processing results

The results are stored in SemiSub_turbWnd_SW.out and SEMISUB_IRRWV.LIS. The .out file contains the outputs defined in the .fst file. The .LIS contains the results of the platform and mooring lines. The .out file can be opened using notepad. The results stored in the .LIS file cannot be plotted directly. Therefore, the “readAQWAResults_SingleFile.exe” is used to exact the mooring tension and platform responses.

The result extraction code requires an input file that define the specifications of the LIS file. You need define the directory of the InputLISFile correctly. The time duration and time step need to be set correctly. So as the mooring property.

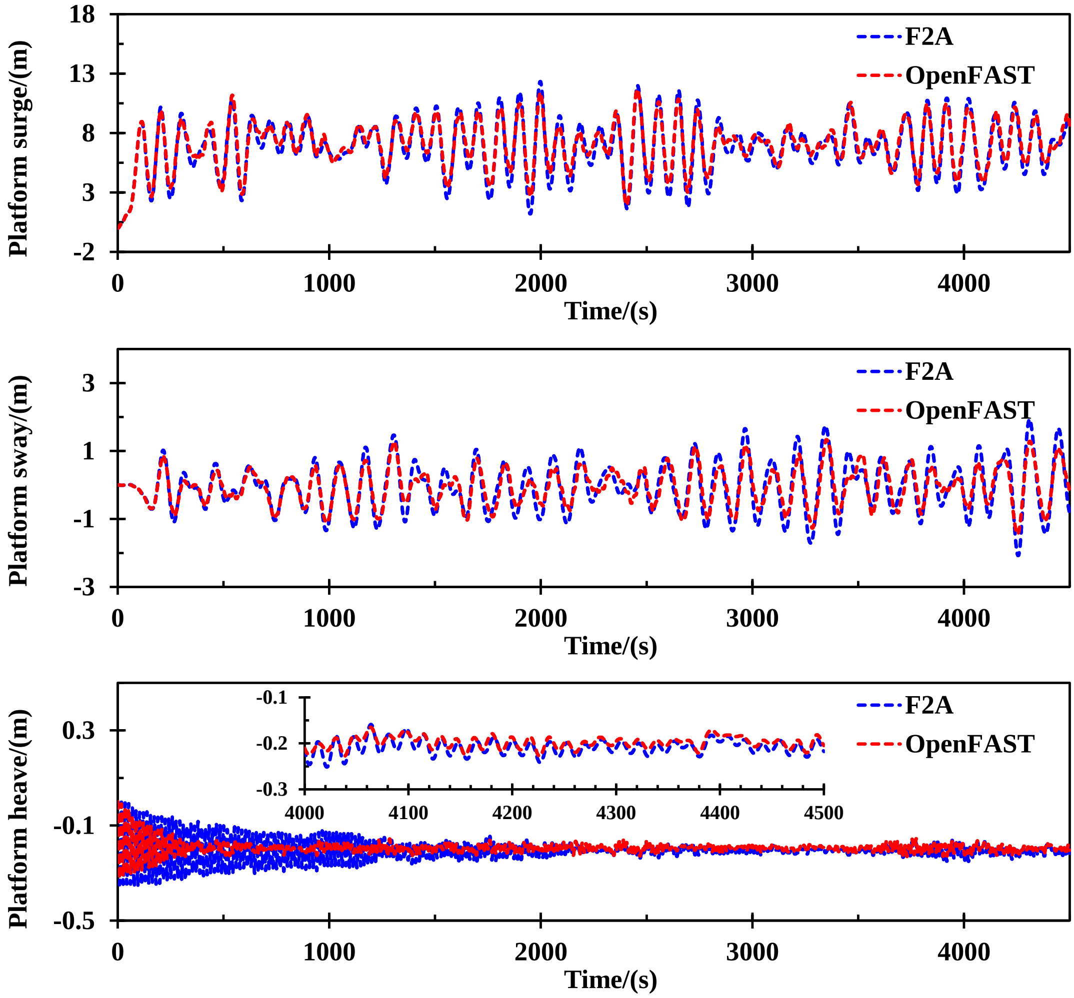
```
! Input file for readAQWAResults_SingleBody which is specific developed for extracting results from the LIS files generated by AQWA.
! The positions, velocities and accelerations of the platform can be output based on the definitions below. The platform is a single body. It is
! --------- Global parameters ----------------------
"SEMISUB_IRRWV.LIS"                    - InputLISFile         - Input LIS file
"SEMISUB_IRRWV"                        - OutFolder            - The target folder to store the result files
2500.0                         - TimeDur              - Duration of each simulation
0.1                            - TimeStep             - Time step of each simulation
! ---------- Details of the LIS file ----------------
1                              - NumBodies            - Number of bodies defined in the LIS file.
!----------- Body 1 -----------------------------------
"Semisub_SEMISUB_IRRWV"                - NameBodies(1)        - Name of the 1st body
True                           - FlagOPMot(1)         - Flag of outputting motions at the 1st body's CoG
True                           - FlagOPVel(1)         - Flag of outputting velocities at the 1st body's CoG
True                           - FlagOPAcc(1)         - Flag of outputting accelerations at the 1st body's CoG
True                           - FlagOPFrc(1)         - Flag of outputting forces at the 1st body's CoG
!---------- Added points ------------------------------
0                              - NumAddedPts          - Number of added points that require output resuts (accelerations only)
! --------- Tension of the morring lines ----------------------
True                           - FlagMLType           - Mooring line type (True: nonlinear catenary, False: linear cable )
3                              - NumMoorLines         - Number of mooring lines
! --------- Wave elevation ----------------------
True                           - FlagWvElv            - Output wave elevation
"WAVE PSN NODE 99999-FIXED"    - CharWvEle            - Character string of the wave elevation line.
```

After correctly setting the input for the result extraction code, then examine the code and the results will be extracted and saved to an individual folder. Note that the platform kinematics are referred to the global coordinate system (with an origin of 0 0 0).

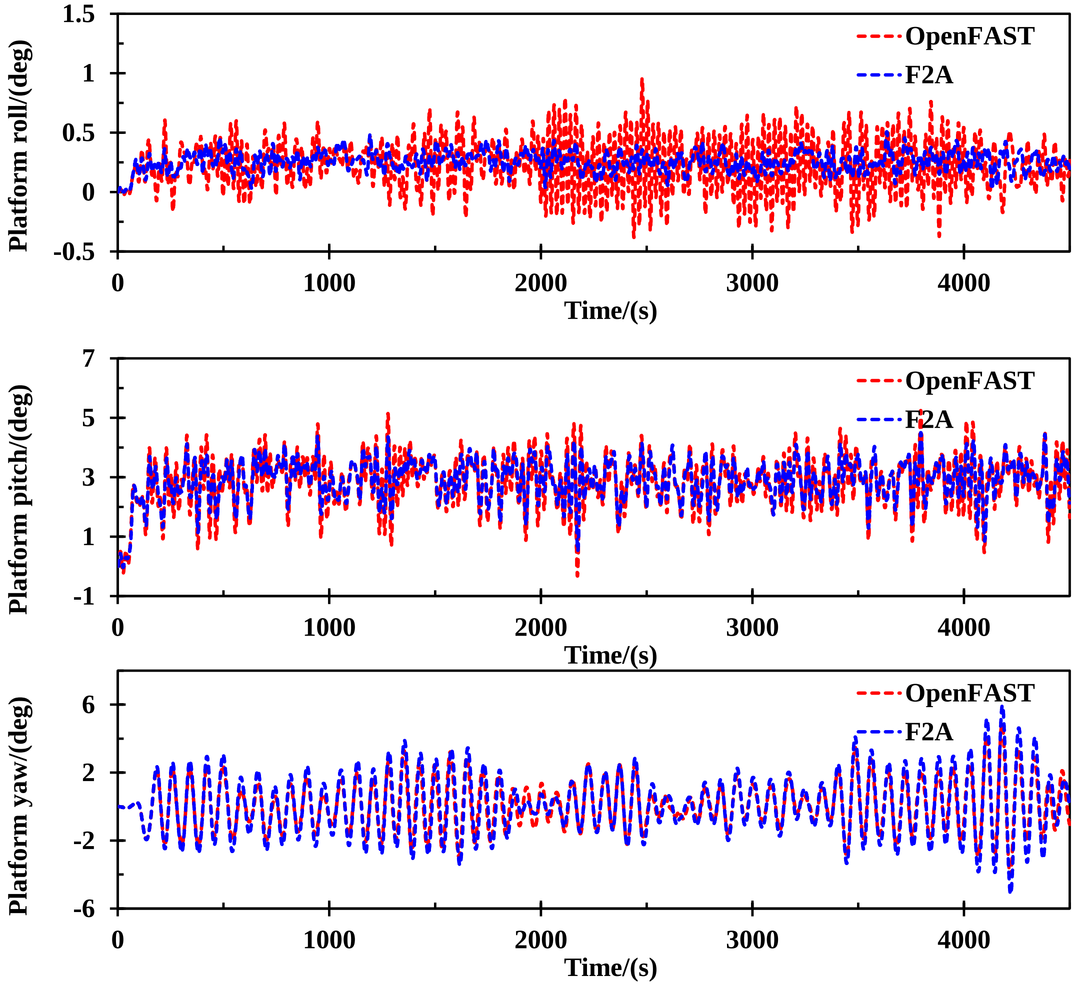
```
G:\StudyJeyla\Research\1Papers\2020English\Semisub\F2A\readAQ\
 InputLISFile= SEMISUB_IRRWV.LIS
Time =      0 s
Time =    100 s
Time =    200 s
Time =    300 s
Time =    400 s
Time =    500 s
Time =    600 s
Time =    700 s
Time =    800 s
Time =    900 s
Time =   1000 s
Time =   1100 s
Time =   1200 s
Time =   1300 s
```

名称	修改日期	类型
SEMISUB_IRRWV_MooringTension.dat	2020/12/15 1:40	DAT 文件
SEMISUB_IRRWV_Semisub_SEMISUB_IRRWV_Acceleration.dat	2020/12/15 1:40	DAT 文件
SEMISUB_IRRWV_Semisub_SEMISUB_IRRWV_Force.dat	2020/12/15 1:40	DAT 文件
SEMISUB_IRRWV_Semisub_SEMISUB_IRRWV_Motion.dat	2020/12/15 1:40	DAT 文件
SEMISUB_IRRWV_Semisub_SEMISUB_IRRWV_Velocity.dat	2020/12/15 1:40	DAT 文件

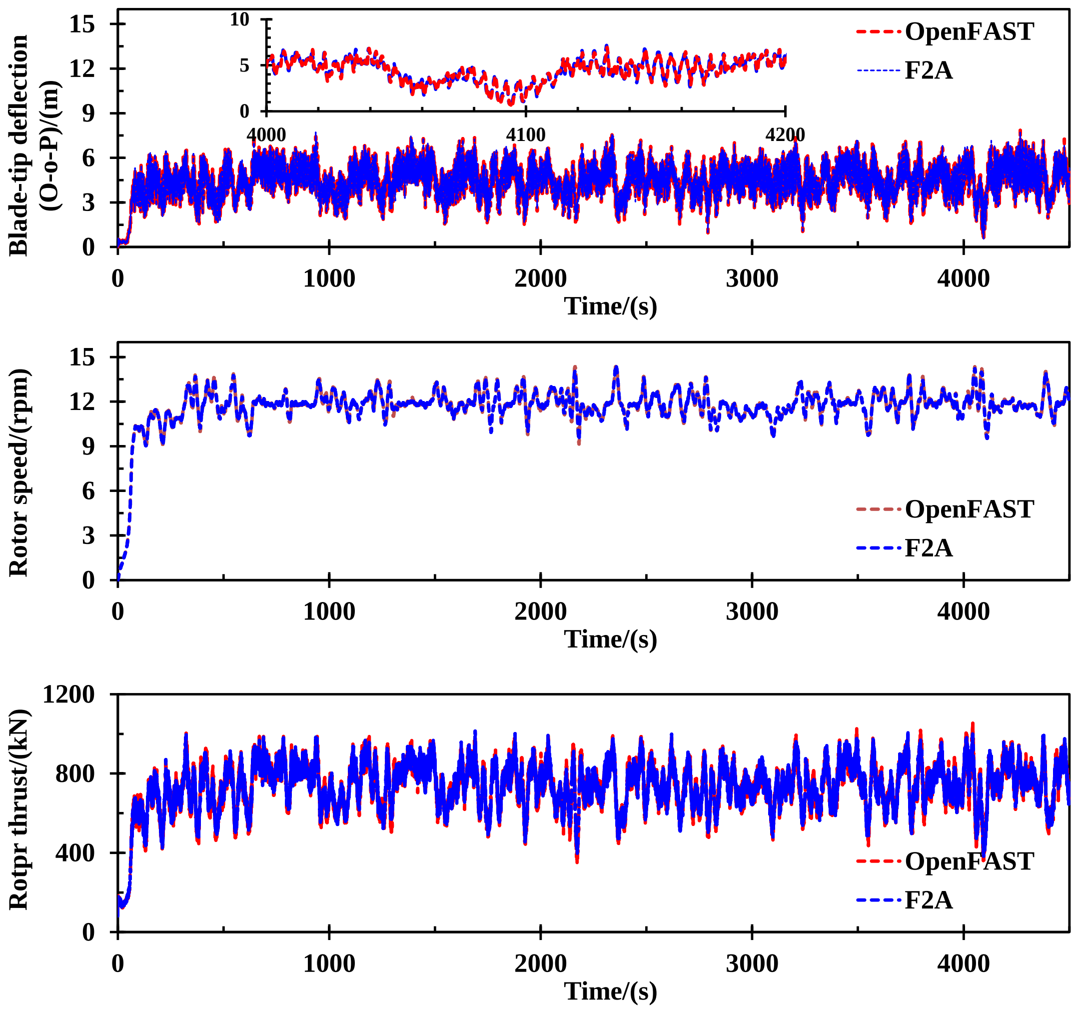
Until here, I have shown all the processes for running F2A and checking the relevant results. I presented a comparison against OpenFAST for a wind-only case. The turbulent wind has an average speed of 11.4 m/s. It is observed that the results calculated by F2A agree well with the predictions of OpenFAST.



Platform surge/(m)
18
13
8
3
-2
0
1000
2000
3000
4000
Time/(s)
F2A
OpenFAST
Platform sway/(m)
3
1
-1
-3
0
1000
2000
3000
4000
Time/(s)
F2A
OpenFAST
Platform heave/(m)
0.3
-0.1
-0.5
0
1000
2000
3000
4000
Time/(s)
-0.1
-0.2
-0.3
4000
4100
4200
4300
4400
4500
F2A
OpenFAST



Platform roll/(deg)
1.5
1
0.5
0
-0.5
0
1000
2000
3000
4000
Time/(s)
OpenFAST
F2A
Platform pitch/(deg)
7
5
3
1
-1
0
1000
2000
3000
4000
Time/(s)
OpenFAST
F2A
Platform yaw/(deg)
6
2
-2
-6
0
1000
2000
3000
4000
Time/(s)
OpenFAST
F2A



Blade-tip deflection (O-o-P)/(m)
OpenFAST
F2A
Time/(s)
Rotor speed/(rpm)
OpenFAST
F2A
Time/(s)
Rotpr thrust/(kN)
OpenFAST
F2A
Time/(s)