Workshop 3: Aqwa Articulations – FPSO and Turret

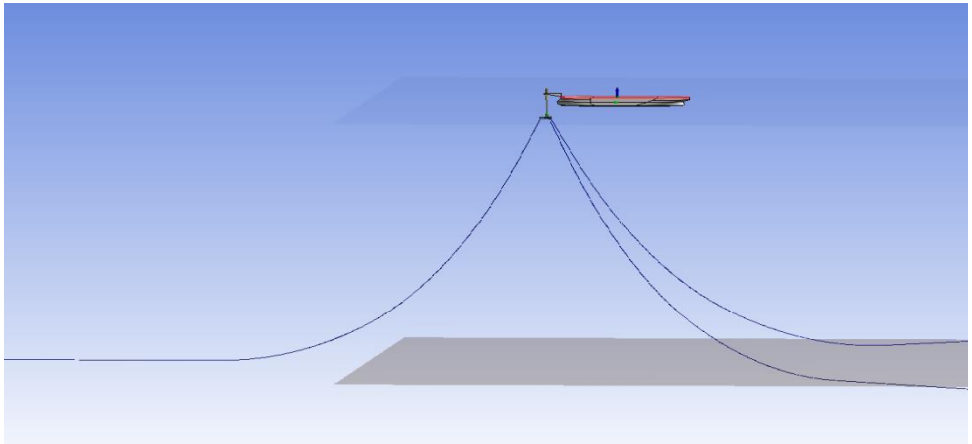
Introduction to Hydrodynamic Analysis with ANSYS Aqwa

ANSYS Release 19.2

FPSO & Turret

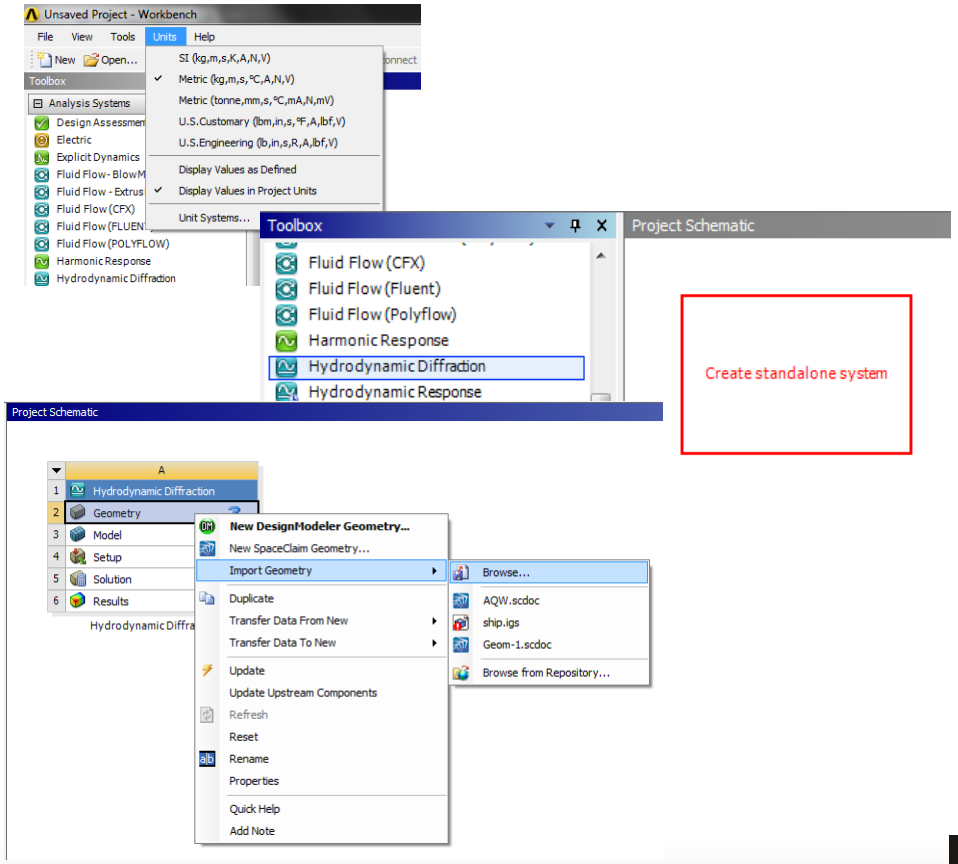
The goal of this workshop is to

- **Create Hydrodynamic Diffraction (HD) system**
- **Import multi-part CAD geometry**
- **Create anchor points and mooring lines**
- **Create turret articulation**
- **Set up Hydrodynamic Response (HR) system**



Create HD System

- **Set Units**
- **Add HD system by drag & drop onto WB Project Schematic page.**
- **RMB on Geometry cell, Import Geometry > Browse, and browse to FPSOTurret.scdoc**

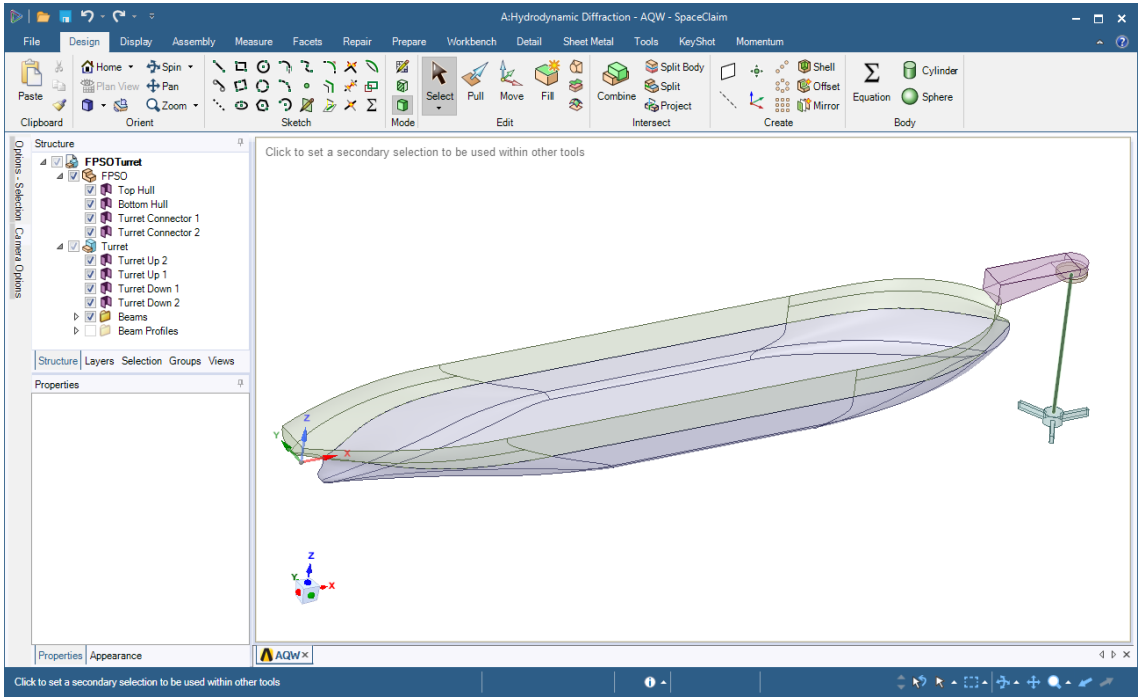


Review Geometry

Double-click on Geometry in the Project Schematic to view the model for this exercise. The geometry consists of an FPSO which will be joined to a moored Turret.

The Turret includes a line body ('Rod'), which will be represented by Morison elements in Aqwa. Note how the line body is assigned a Cross Section (CircularTube1).

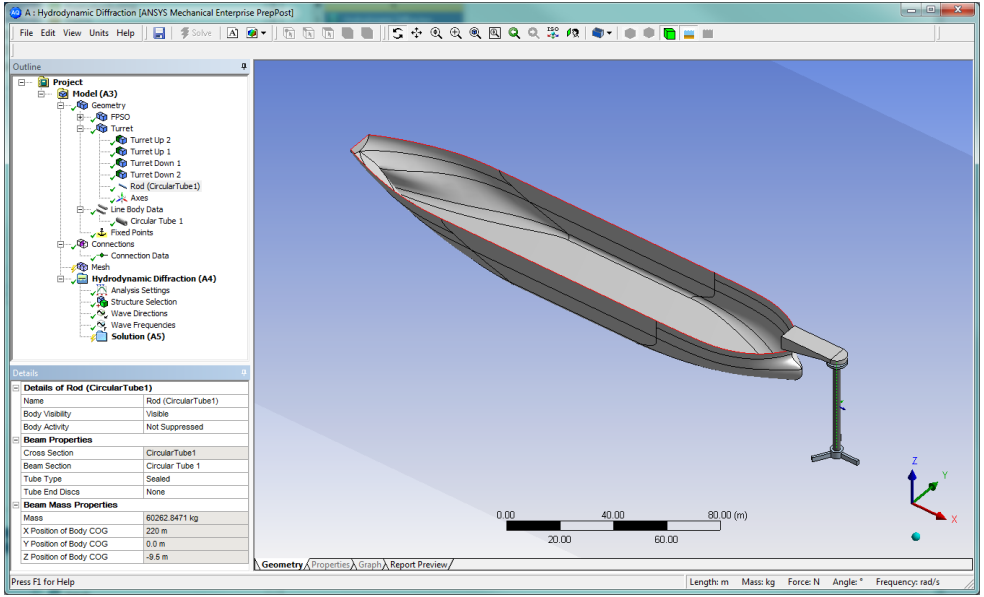
Close SpaceClaim.



Adding Aqwa Specific Parameters

Double-click on the Model cell in the Project Schematic.

Note that the line body in the Turret structure is now graphically represented with the diameter corresponding to its Cross Section in SpaceClaim.

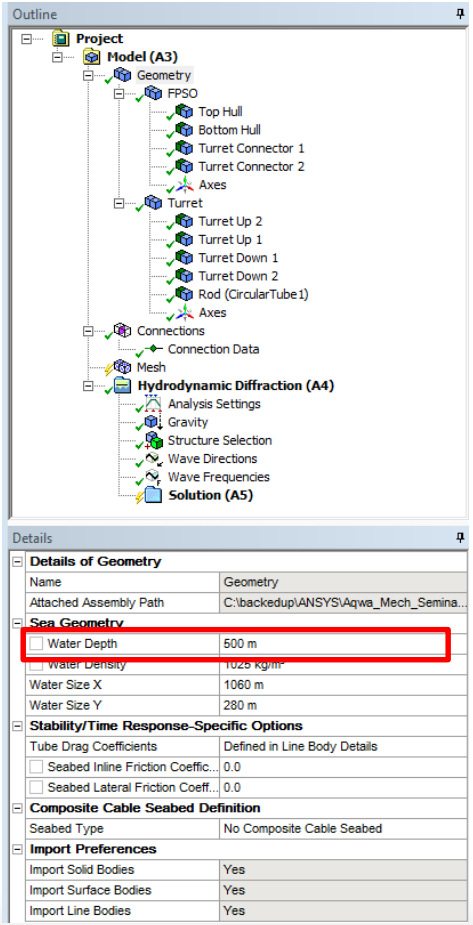


Details

Details of Circular Tube 1	
Name	Circular Tube 1
Solver Line Type	Cylindrical (TUBE)
Geometric Properties	
Cross Section Name	CircularTube1
Cross Section Type	Circular Tube
Inner Radius	1.48 m
Outer Radius	1.5 m
Cross Section Area	0.18724 m²
Second Moment of Area	0.20785 m⁴
Mass Properties	
Material Density	7850 kg/m³
Inertia/Unit Length	1631.65333 (kg.m²)/m
Hydrodynamic Properties	
Displaced Area	7.06858 m²
Transverse Drag Coefficient	0.75
Axial Drag Coeffcient	0.016
Added Mass Coefficient	1
Inertia Coefficient	2

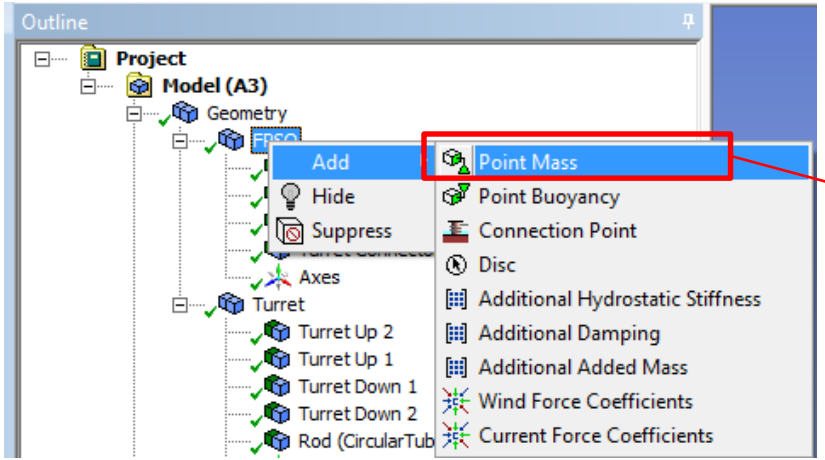
Global Parameters

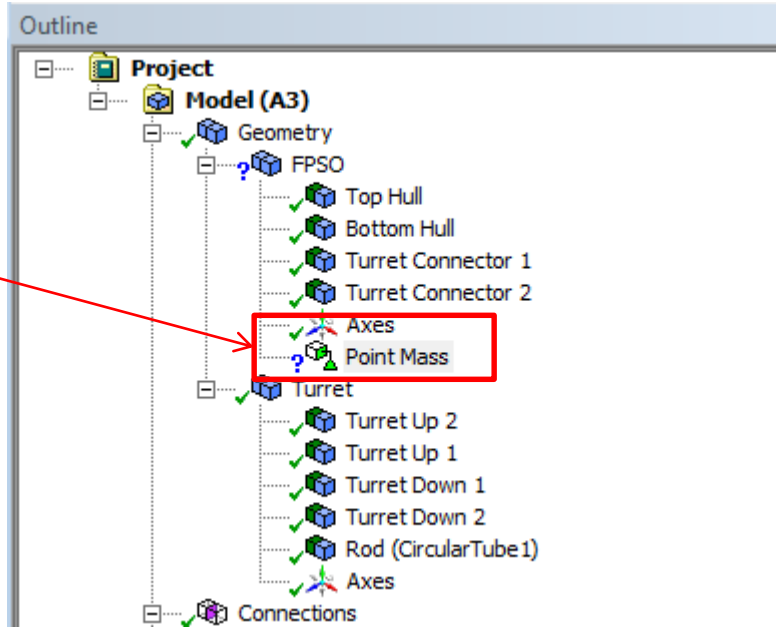
Set the Water Depth to 500m in the Details of Geometry panel.



Provide Additional Aqwa Elements

For each vessel/structure (FPSO & Turret) provide a Point Mass element





FPSO Point Mass Input

As before, if Mass Definition is Program Controlled the mass will equal the displacement.

Set k_{XX}, k_{YY} and k_{ZZ} and VCG for FPSO using the same formulation as in the ship model in Workshop 1

Details

Details of Point Mass	
Name	Point Mass
Visibility	Visible
Activity	Not Suppressed
Mass Properties	
Mass Definition	Program Controlled
X	0.0 m
Y	0.0 m
Z	8.5 m
Mass	1 kg
Inertia Properties	
Define Inertia Values By	Radius of Gyration
Kxx	13.6 m
Kyy	50 m
Kzz	52 m
Ixx	184.96 kg.m²
Ixy	0.0 kg.m²
Ixz	0.0 kg.m²
Iyy	2500 kg.m²
Iyz	0.0 kg.m²
Izz	2704 kg.m²

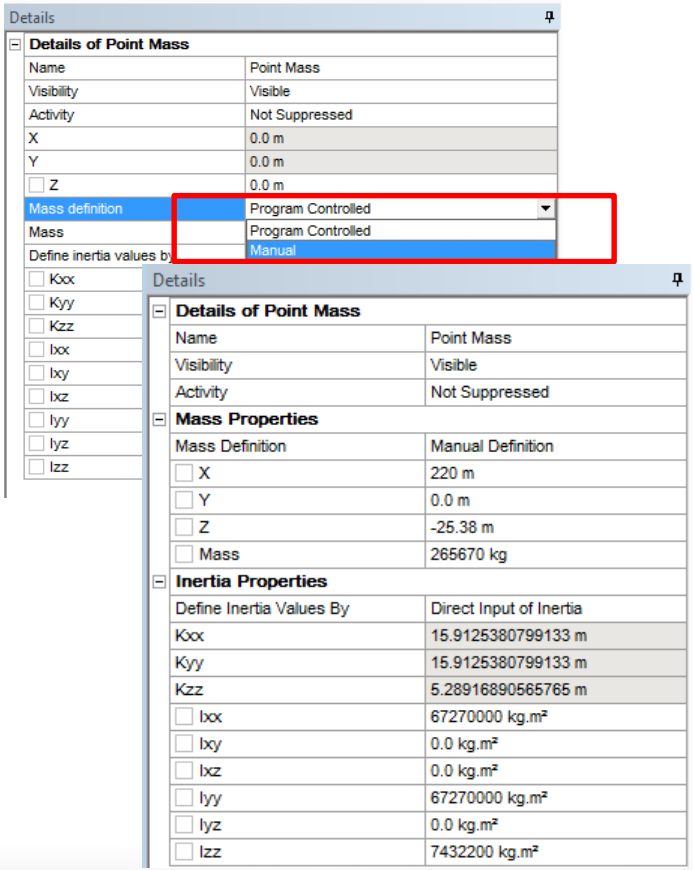
Turret Point Mass Input

Set the Mass definition to Manual and specify a Mass of 265.670 tonnes

Set Define Inertia Values by to Direct Input of Inertia, and set I_{XX}, I_{YY} and I_{ZZ} to:

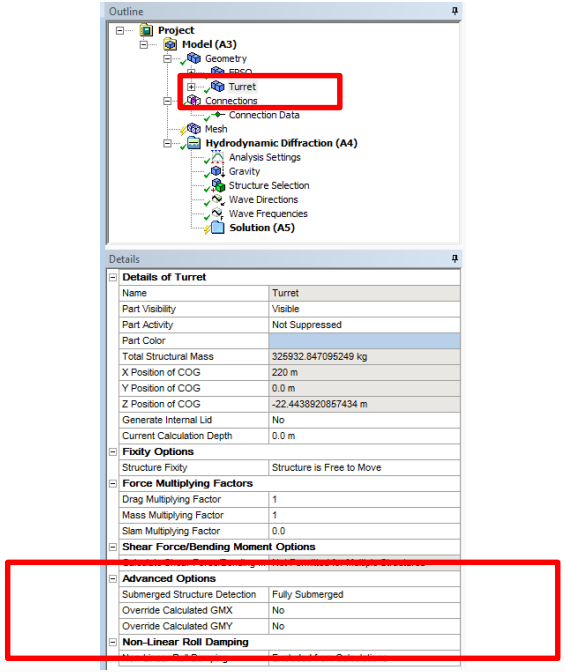
- **I_{XX} = 67270000 kg.m² (you can just type '6.727e7')**
- **I_{YY} = 67270000 kg.m²**
- **I_{ZZ} = 7432200 kg.m²**

Set the VCG (Z coordinate) to -25.38 m and the LCG (X coordinate) to 220 m



Turret Submerged Structure Setting

Since the Turret does not have diffracting elements at the water line we need to set up the structure as a Fully Submerged Body.



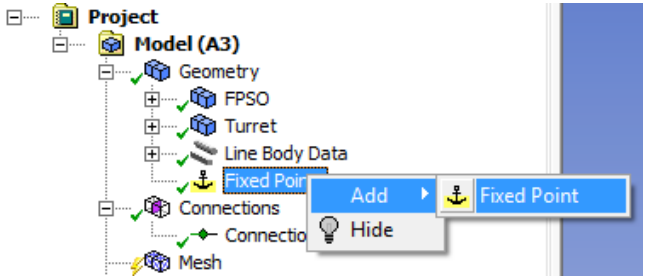
- **Select Turret In the Geometry tree**
- **Set Submerged Structure Detection to Fully Submerged**

Anchor Connection Points

Select the Fixed Points object in the tree and add three fixed points for the mooring system representing the anchor locations

Set the x, y, z coordinates as follows:

- **Anchor 1** **-700m, 700m, -500m**
- **Anchor 2** **-700m, -700m, -500m**
- **Anchor 3** **1300m, 0m, -500m**



Connection Points

Select the part FPSO and add a connection point

Set the X, Y, Z, coordinates as follows and rename Turret Connection;

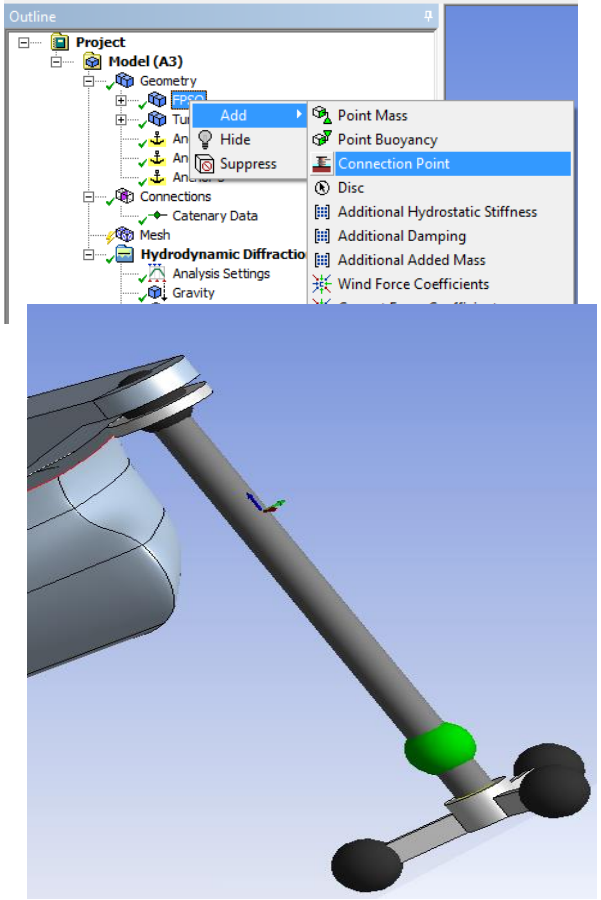
- **Turret Connection 220m, 0m, 13m**

Select the part Turret and add four connection points

Define names and set the X, Y, Z, coordinates as follows;

- **FPSO Connection 220m, 0m, 12m**
- **Mooring 1 215.0m, 8.66m, -32.0m**
- **Mooring 2 215.0m, -8.66m, -32.0m**
- **Mooring 3 230.0m, 0.0m, -32.0m**

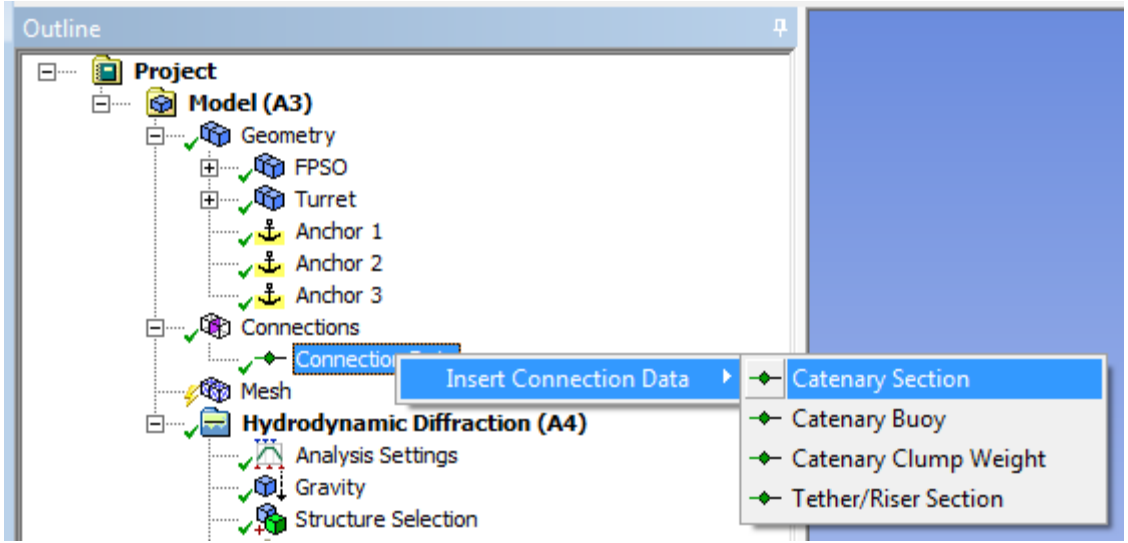
Check the locations of the connection points. Note that all coordinates defined are in the global system (FRA)



Set Up Mooring Line Properties

As in Workshop 2 we are going to use composite catenary lines for the mooring system. These are lines made up of one or more segments with varying properties e.g. chain/wire/chain.

Select Connections > Connection Data > Insert Connection Data > Catenary Section



Mooring Line Properties

Provide data for Mass/Unit Length, Equivalent Cross Sectional Area, Stiffness, Maximum Tension and Equivalent Diameter as below for three catenary sections. Use the Duplicate function to avoid entering the same data many times.

Details

Details of Catenary Section 1	
Name	Catenary Section 1
Section Properties	
Mass/Unit Length	150 kg/m
Equivalent Cross-Sectional A...	0.01 m²
Stiffness, EA	600000000 N
Maximum Tension	7500000 N
Bending Stiffness, EI	0.0 N.m²
Axial Stiffness Coefficient k1	0.0 N
Axial Stiffness Coefficient k2	0.0 N
Axial Stiffness Coefficient k3	0.0 N
Section Hydrodynamic Properties	
Added Mass Coefficient	1
Transverse Drag Coefficient	1
Equivalent Diameter	0.2 m
Longitudinal Drag Coefficient	0.025

Details

Details of Catenary Section 2	
Name	Catenary Section 2
Section Properties	
Mass/Unit Length	120 kg/m
Equivalent Cross-Sectional A...	0.01 m²
Stiffness, EA	900000000 N
Maximum Tension	7500000 N
Bending Stiffness, EI	0.0 N.m²
Axial Stiffness Coefficient k1	0.0 N
Axial Stiffness Coefficient k2	0.0 N
Axial Stiffness Coefficient k3	0.0 N
Section Hydrodynamic Properties	
Added Mass Coefficient	1
Transverse Drag Coefficient	1
Equivalent Diameter	0.25 m
Longitudinal Drag Coefficient	0.025

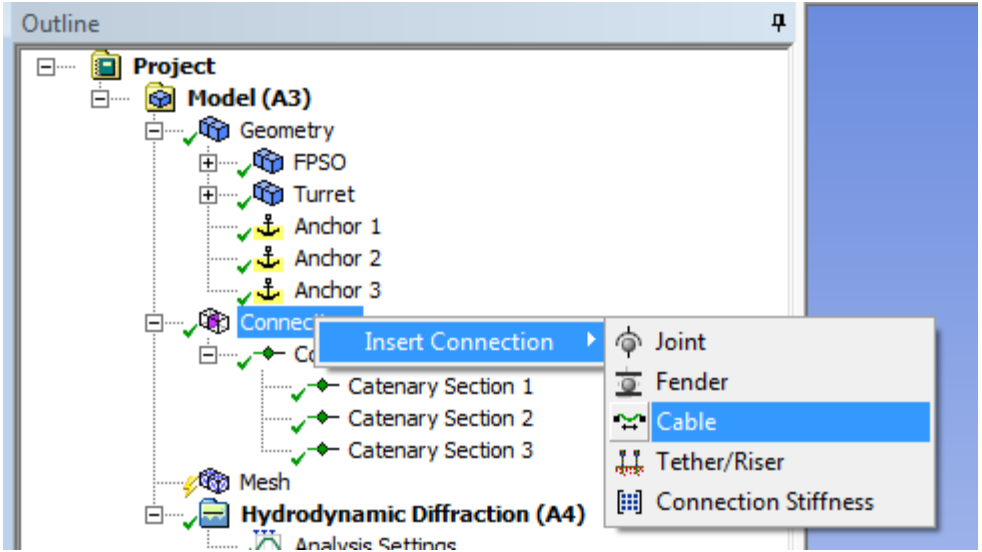
Details

Details of Catenary Section 3	
Name	Catenary Section 3
Section Properties	
Mass/Unit Length	170 kg/m
Equivalent Cross-Sectional A...	0.01 m²
Stiffness, EA	900000000 N
Maximum Tension	7500000 N
Bending Stiffness, EI	0.0 N.m²
Axial Stiffness Coefficient k1	0.0 N
Axial Stiffness Coefficient k2	0.0 N
Axial Stiffness Coefficient k3	0.0 N
Section Hydrodynamic Properties	
Added Mass Coefficient	1
Transverse Drag Coefficient	1
Equivalent Diameter	0.2 m
Longitudinal Drag Coefficient	0.025

Mooring Line Connections

To add a line select Connections > Insert Connection > Cable

Define line connections and composition



Mooring Line Connections

Create cable 1 using the information highlighted opposite

The composition of the line is now defined

- **Segment allocation**
- **Line length**

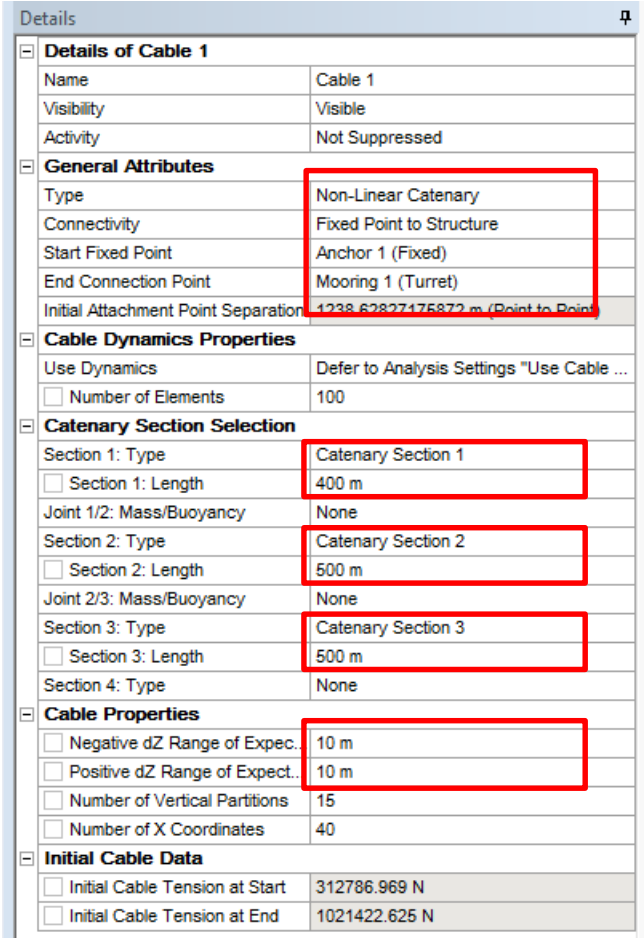
Segments are defined from the anchor location up to the connection point on the turret

Section 1 type should be set to Catenary section 1

Length 400 m

Repeat for sections 2 and 3 as shown

Finally set the dZ Range parameters under Cable Properties to 10m



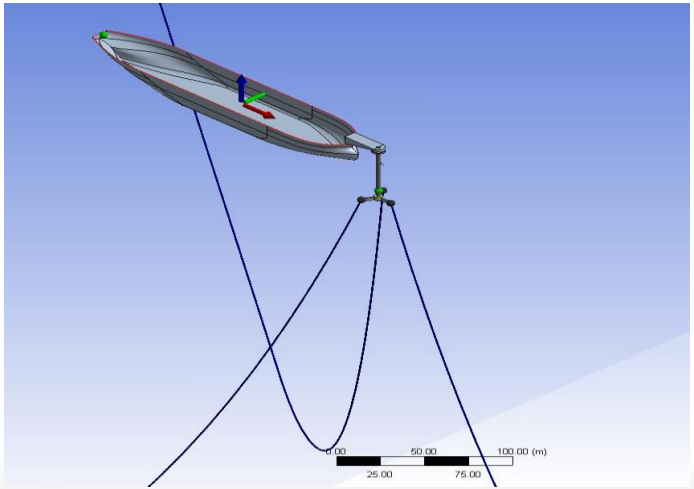
Mooring Line Connections

Use the same information to populate cables 2 and 3 (using Duplicate to save data entry).

Change the fixed point and end point connections as follow;

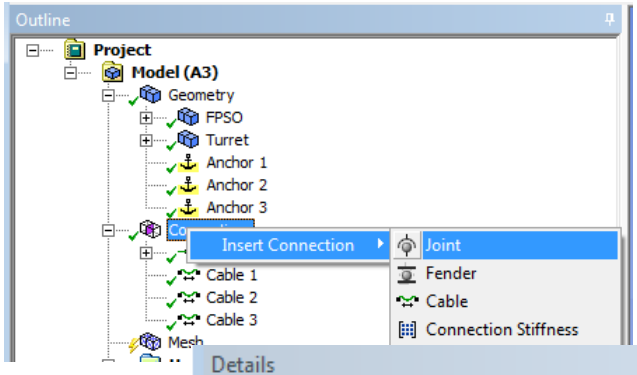
- **Cable 2 Anchor 2 (Fixed), Mooring 2 (Turret)**
- **Cable 3 Anchor 3 (Fixed), Mooring 3 (Turret)**

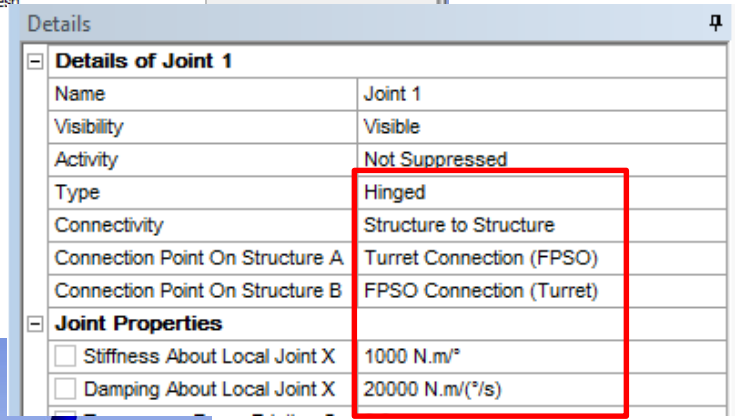
Select Connections in the Outline to see the final mooring configuration

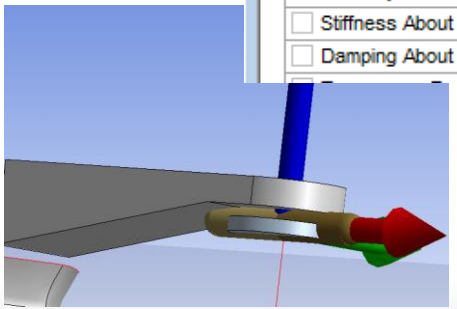


Articulation

- Select Connections in the outline and Insert Connection > Joint
- Set the Joint type to Hinged
- Set the connection points as shown
- Set the stiffness about the X axis to 1000N/°
- Set the damping about the X axis to 20000N.m/(°/s)
- Note that the orientation of the hinge is incorrect
- The axis system local to the hinge can be rotated







Articulation

To change the joint axis, under Joint 1, select Joint Axes On Structure A

Change the Alignment Method to Direction Entry as shown

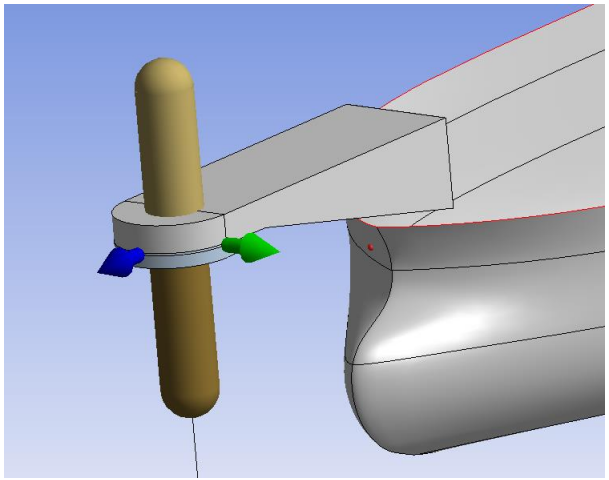
Then change the Rotation About Local Y to 90

Do likewise for Joint Axes On Structure B

Finally confirm the hinge is orientated correctly

Details

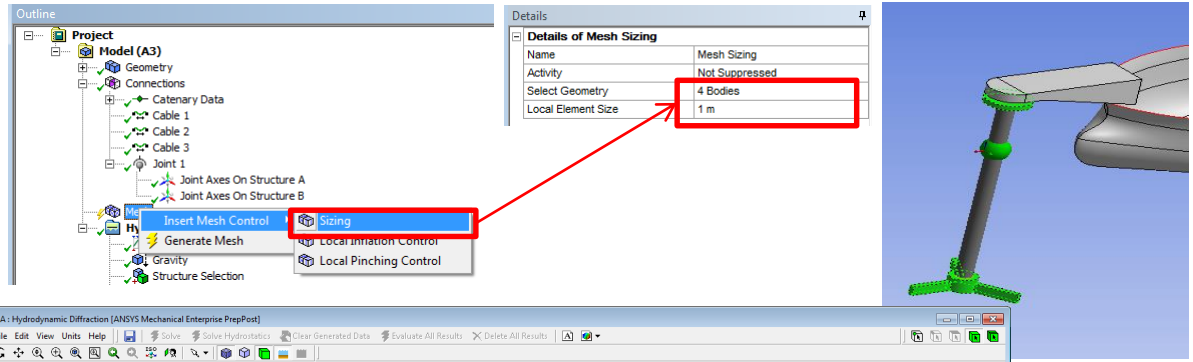
Details of Joint Axes On Structure A	
Name	Joint Axes On Structure A
Visibility	Visible
Alignment Method	Direction Entry
Rotation About Global Z	0 °
Rotation About Local Y	90 °
Rotation About Local X	0 °
Unit Vector X	[0, 0, -1]
Unit Vector Y	[0, 1, 0]
Unit Vector Z	[1, 0, 0]

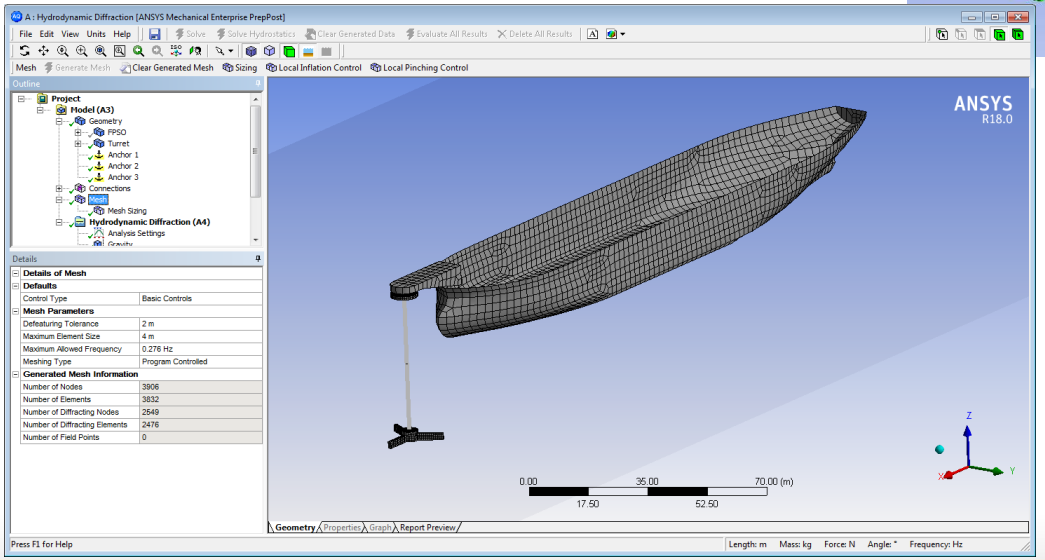


Meshing

- Set Max Element Size to 4m
- Apply a Mesh Sizing Control to the Turret with Local Element Size of 1m
- Generate Mesh

Hint: When scoping the geometry for the Mesh Sizing select the bodies in the turret from top to bottom





Analysis Settings

Set Ignore Modelling Rule Violations to “Yes” (ask your instructor for more info)

Set Include Multi-Directional Wave Interaction to “No”

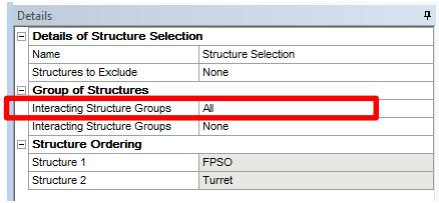
Set Calculate Full QTF Matrix to “No”

Details

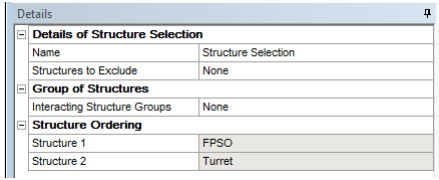
Details of Analysis Settings	
Name	Analysis Settings
Parallel Processing	Program Controlled
Generate Wave Grid Pressures	Yes
Wave Grid Size Factor	2
Common Analysis Options	
Ignore Modelling Rule Violations	Yes
Calculate Extreme Low/High Frequencies	Yes
Calculate Drift Coefficients	Yes
Include Multi-Directional Wave Interaction	No
Near Field Solution	Program Controlled
Linearized Morison Drag	No
QTF Options	
Calculate Full QTF Matrix	No
Output File Options	
Full QTF Matrix	No
Field Point Wave Elevation	Yes
Source Strengths	No
Potentials	No
Centroid Pressures	No
Element Properties	No
ASCII Hydrodynamic Database	No
Example of Hydrodynamic Database	No

Structure Selection

Structure Selection enables the definition of interacting structure groups (for multi-body problems). By default all vessels are assumed interacting.



To reduce the computation time select the first Interacting Structure Groups and set this to None by clicking in blank space in the graphics window and selecting Apply



Wave Directions and Frequencies

Computing additional wave directions is computationally cheap. In Wave Directions, increase the Number of Intermediate Directions to 11.

Details

Details of Wave Directions	
Name	Wave Directions
Type	Range of Directions, No Forward Speed
Required Wave Input	
Wave Range	-180° to 180°
Interval	30°
Number of Intermediate Directions	11

The computational cost scales linearly with the number of frequencies, however, so we will reduce this to 15. In Wave Frequencies:

Details

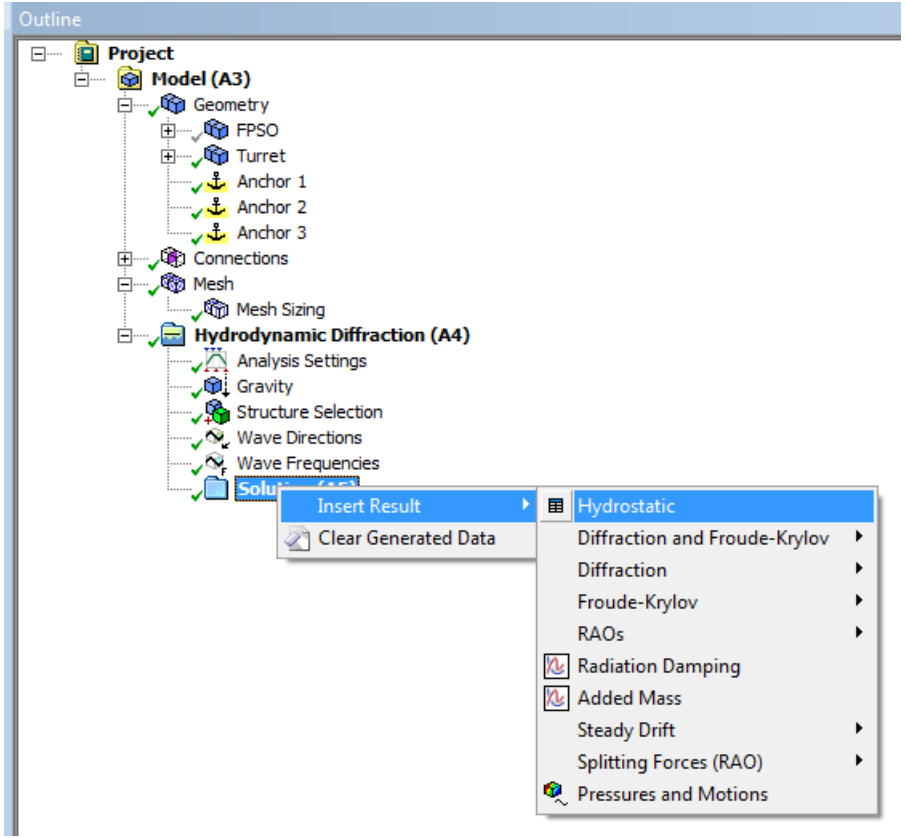
Details of Wave Frequencies	
Name	Wave Frequencies
Intervals Based Upon	Frequency
Frequency/Period Definition	
Range	Program Controlled
Total Number of Frequencies	15

Review Results

Solve full analysis

Insert some results

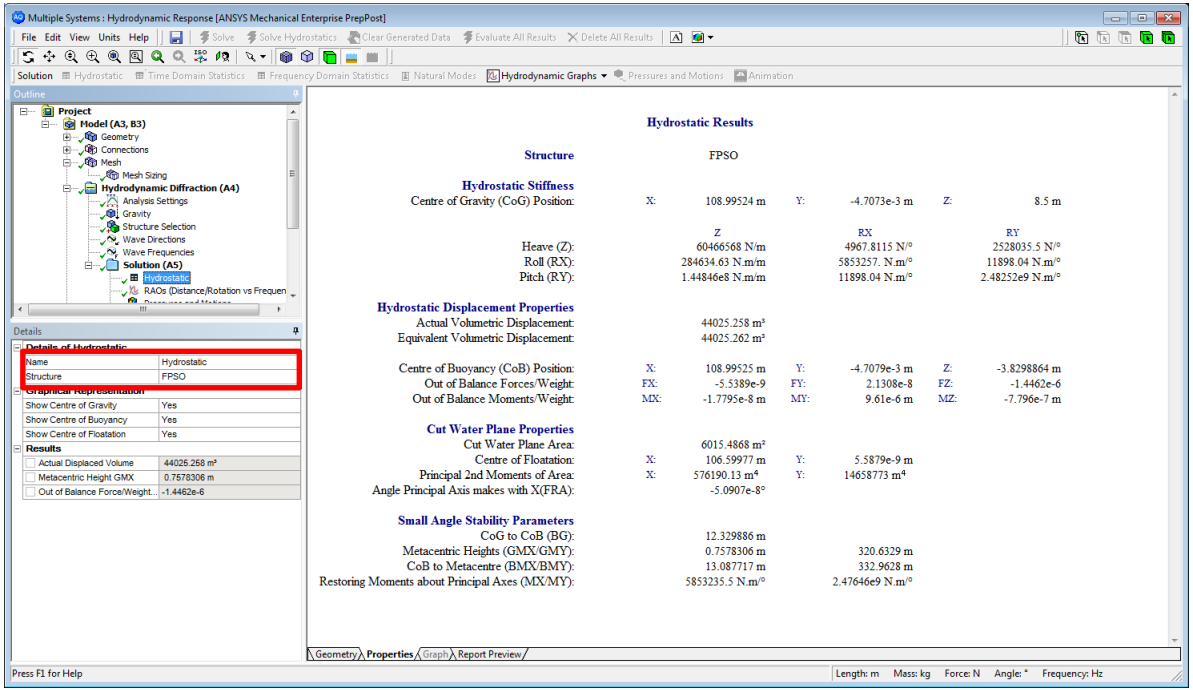
- **Hydrostatic Table for FPSO**
- **Hydrodynamic Graphs**
  - **RAOs in X and Z for FPSO with a wave direction of -180 degrees**
- **Pressures and Motions**
  - **Since we have two non-interacting structures it is possible to plot information for each of these individually**



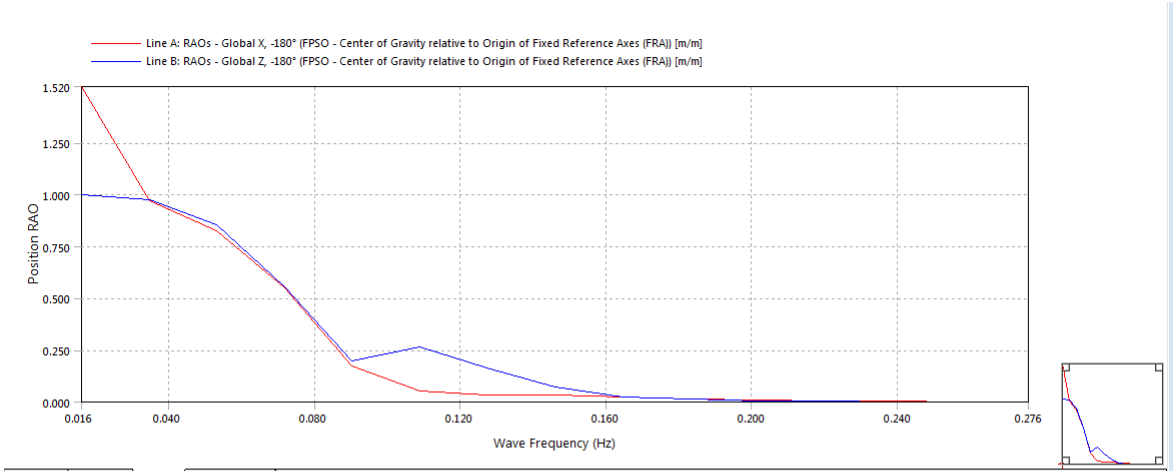
Hydrostatics

When selected these results appear on the Properties tab.

Since we now have two structures, ensure the required one is selected



Hydrodynamic Graphs

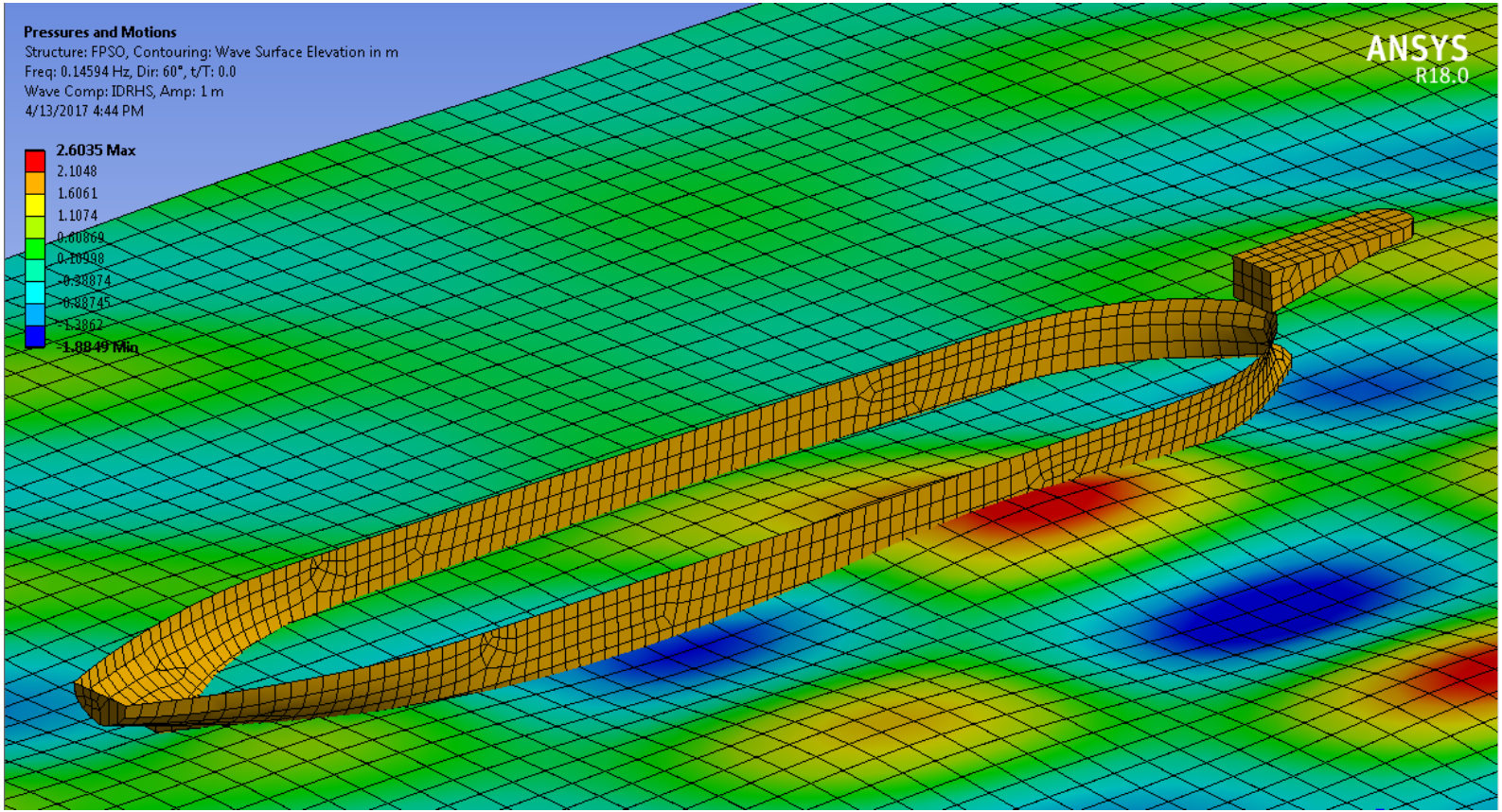


Geometry | Properties | **Graph** | Report Preview

Tabulated Results Data

Wave Frequency (Hz)	Line A (m/m)	Line B (m/m)
0.01592	1.52039	0.99727
0.03449	0.96873	0.97344
0.05307	0.82319	0.85679
0.07164	0.54906	0.55408
0.09022	0.17193	0.19718
0.10879	0.05171	0.26396
0.12737	0.03314	0.16249
0.14594	0.03502	0.07336
0.16452	0.02518	0.02589
0.18309	0.01581	0.0128
0.20167	0.01048	4.2231e-3
0.22024	6.80732e-3	2.83984e-3
0.23882	3.97374e-3	1.32574e-3
0.25739	2.56115e-3	8.32347e-4
0.27597	1.64725e-3	3.45104e-4

Hydrodynamic Pressures and Motions

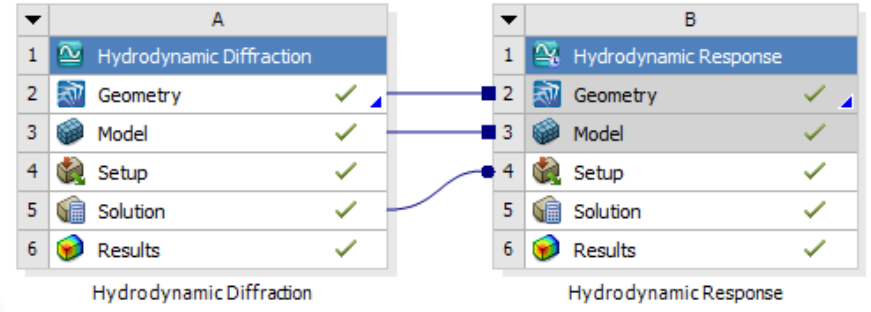


A Note on Connections

In this example the mooring lines and articulation have been defined before the Hydrodynamic Diffraction system has been Solved. However, it must be noted that the effects of these connections will not be seen in the Hydrodynamic Diffraction results.

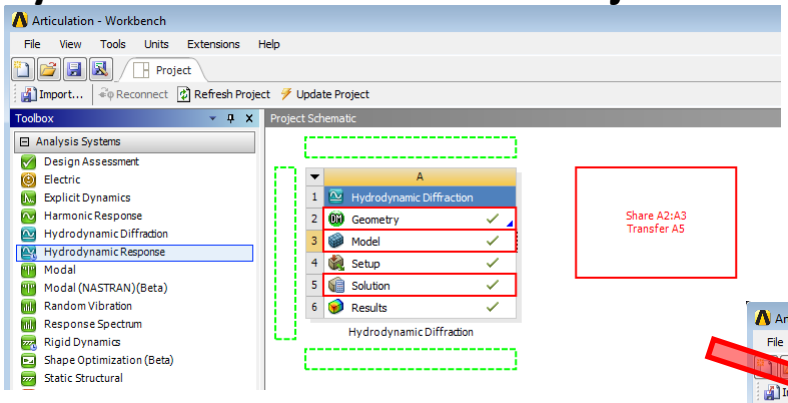
It is possible to enter a 6x6 Connection Stiffness matrix (under Connections), applied between one structure and the ground or between two structures, which is accounted for in the HD system. However, in many cases the stiffness matrix can only be approximated.

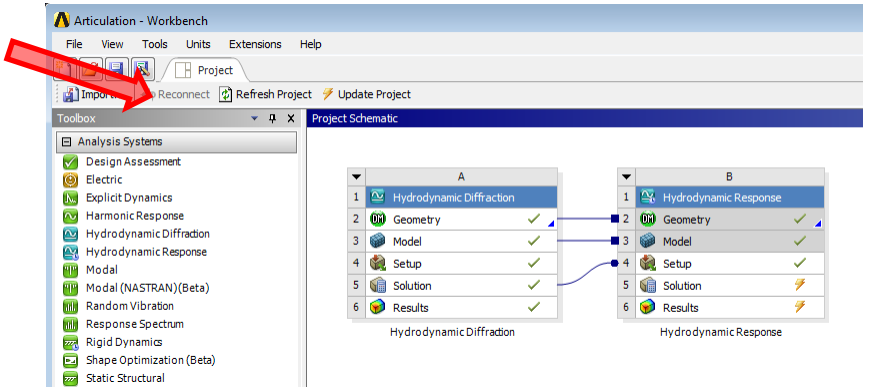
To fully assess the effects of the mooring lines and articulation on the system the user must view the results of a Hydrodynamic Response analysis. This is covered next.



Time Domain Simulation

Add an HR system by dragging and dropping on to the Solution cell of the HD system on the Workbench Project Schematic page





Analysis Settings

Set Computation Type to Time Response Analysis.

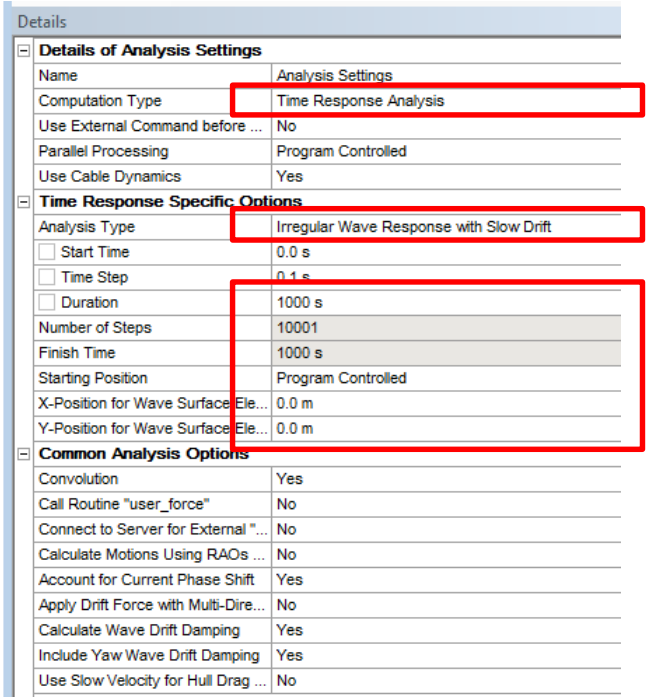
Set Starting Position to Program Controlled.
Note that when set to Program Controlled a Stability Analysis will automatically be undertaken before the Time Response Analysis is processed.

Set Analysis Type to Irregular Wave Response with Slow Drift

Set Time Step to 0.1 seconds

Set Duration to 1000 seconds

Check that Use Cable Dynamics is set to Yes



Define the Environment

RMB on Hydrodynamic Time Response > Insert > Irregular Wave > Pierson-Moskowitz

Set Direction of Spectrum to 170°

Set Significant Wave Height to 4m

Set Zero Crossing Period to 8s

RMB on Hydrodynamic Time Response > Insert > Current

Set a 1m/s current at the surface at 175° (equivalent to constant with depth) by clicking on the Current Definition Data table and entering the data as shown. Note that since we have not defined any hull drag coefficients for the FPSO there will be no current loading on that vessel. The Turret, however, will be loaded since it is modelled in part by a tubular Morison element.

Run the analysis by clicking on Solution and Solve

Details

Details of Irregular Wave 1	
Name	Irregular Wave 1
Visibility	Visible
Activity	Not Suppressed
Wave Range Defined By	Frequency
Wave Spectrum Details	
Wave Type	Pierson-Moskowitz
Direction of Spectrum	170°
Wave Spreading	None (Long-Crested Waves)
Spectrum Presentation Method	1D Graph
Seed Definition	Program Controlled
Number of Spectral Lines Definiti...	Program Controlled
Omit Calculation of Drift Forces	No
Start and Finish Frequency Defi...	Program Controlled
Start Frequency	0.05127 Hz
Finish Frequency	0.45167 Hz
Significant Wave Height	4 m
Zero Crossing Period	8 s
Export CSV File	Select CSV File...
Cross Swell Details	
Wave Type	None

Details

Details of Current 1	
Name	Current 1
Visibility	Visible
Activity	Not Suppressed
Import Data From CSV	
Import CSV File	Select CSV File...

Current Definition Data

Depth (m)	Velocity (m/s)	Direction (°)
0.0	1	175

Check Solution

RMB Solution to Insert Result > Structure Position > Actual Response

Select FPSO for the Structure and Global RZ as the Component of motion

Obtain forces on the turret joint connection - Insert Result > Joint Forces

Details

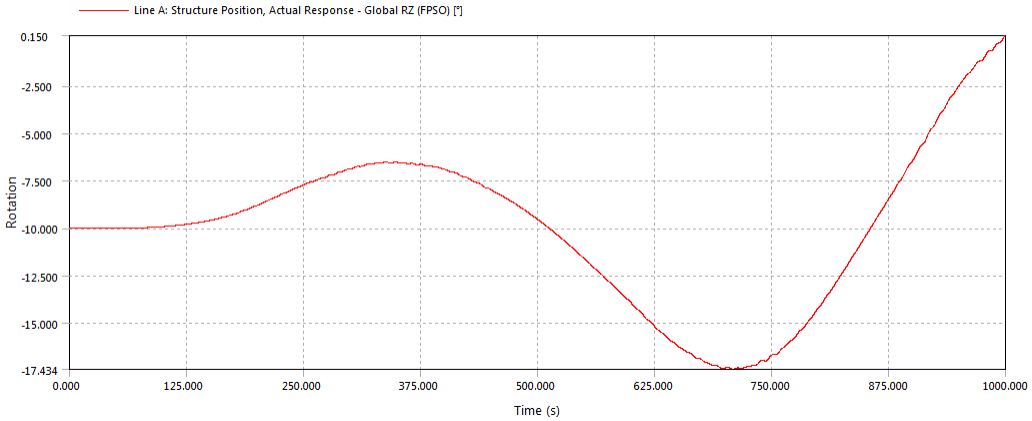
Details of Structure Position, Actual Response	
Name	Structure Position, Actual Response
Presentation Method	Line
Axes Selection	Distance/Rotation vs Time
Line A	
Structure	FPSO
Type	Structure Position
SubType	Actual Response
Component	Global RZ

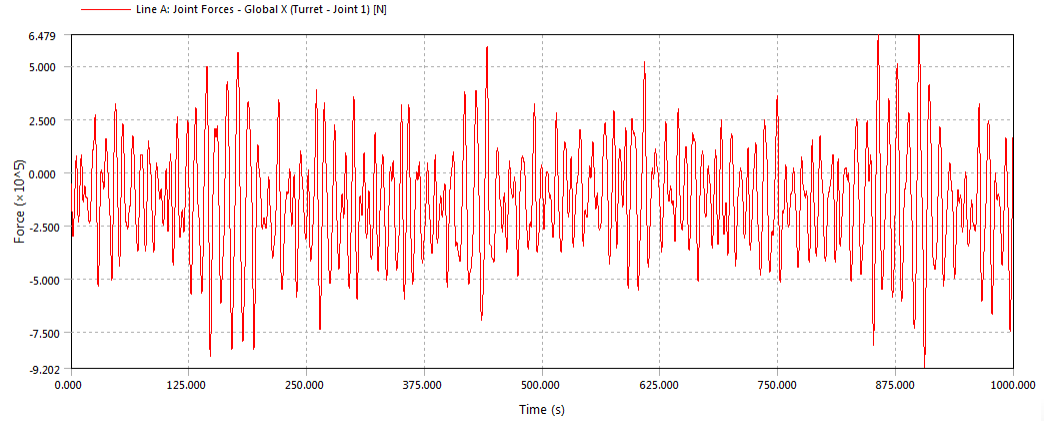
Details

Details of Joint Forces	
Name	Joint Forces
Presentation Method	Line
Axes Selection	Force/Moment vs Time
Line A	
Structure	Turret
Type	Joint Forces
Component	Global X
Connection	Joint 1

Evaluate All Results

Typical Results





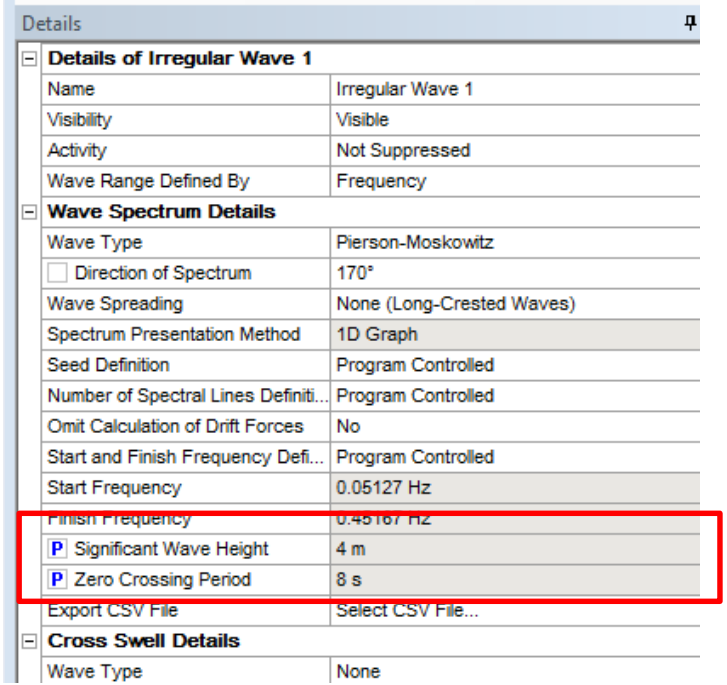
Setting Up Parameters

For design studies, several input parameters can be set as variable (such as environmental parameters)

Click the check box on the left hand side of the Significant Wave Height in the Irregular Wave Details

The letter P will indicate that this value is a variable parameter and the value input box will be locked.

Repeat for the Zero Crossing Period



Setting Up Output Parameters

In the Solution, set as output parameter the Joint Forces Minimum and Maximum Value.

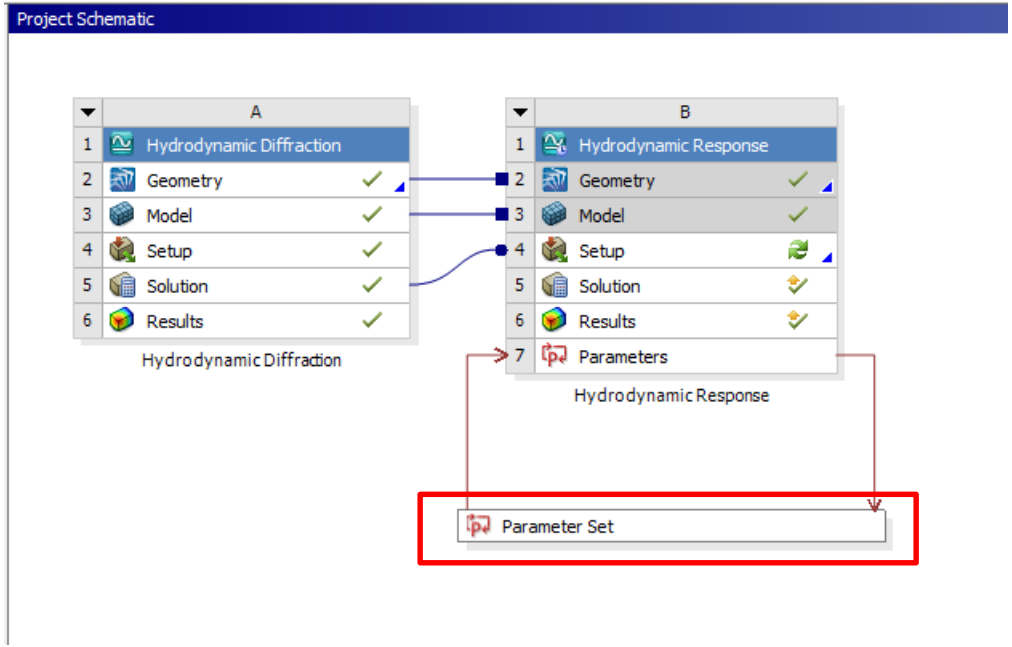
Details

Details of Joint Forces	
Name	Joint Forces
Presentation Method	Line
Axes Selection	Force/Moment vs Time
Export CSV File	Select CSV File...
Line A	
Structure	Turret
Type	Joint Forces
Component	Global X
Connection	Joint 1
Abscissa Position of Minimum	905.5 s
Abscissa Position of Maximum	856.5 s
P Minimum Value	-919928.125 N
P Maximum Value	647920 N
Line B	
Structure	Undefined...

Setting Up Parameters

Go back to Project Schematic

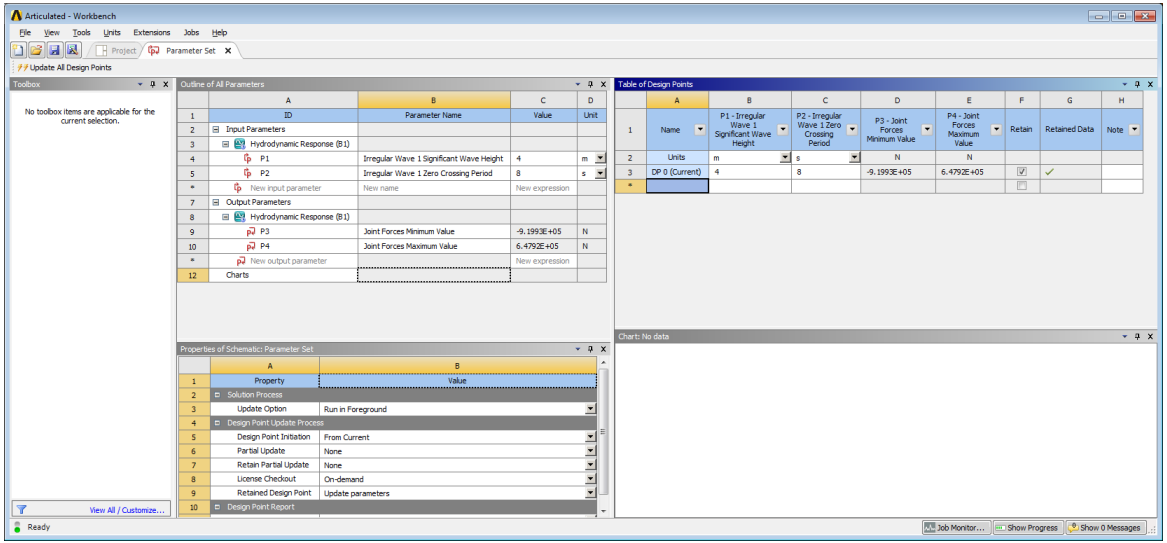
You will see that the Parameter Set box has appeared. Double-click on the Parameter Set box



Design Points View

Design Points view in WorkBench consists of several sub-views;

- **Outline of all parameters**
- **Table of design points**
- **Properties**
- **Chart**
- **Parameters Chart Toolbox**



Setting Up Design Points

Go to Table of Design Points and vary both the wave height and zero crossing period, as shown to define three additional design points. Save the Project

Click Update All Design Points

The solution will take several minutes, so be patient.

Note the Retained Data column. If one or more of these boxes are checked then the complete solution for that particular design point(s) will be saved. Otherwise only the initial design point (marked as Current) is preserved.

Table of Design Points

	A	B	C	D	E	F	G	H
1	Name	P1 - Irregular Wave 1 Significant Wave Height	P2 - Irregular Wave 1 Zero Crossing Period	P3 - Joint Forces Minimum Value	P4 - Joint Forces Maximum Value	Retain	Retained Data	Note
2	Units	m	s	N	N			
3	DP 0 (Current)	4	8	-9.1993E+05	6.4792E+05	☑	✓	
4	DP 1	4	10			☐		
5	DP 2	3	9			☐		
6	DP 3	3	11			☐		
*						☐		

Design Points Results

Review the results table for each design point

Table of Design Points

	A	B	C	D	E	F	G	H
1	Name	P1 - Irregular Wave 1 Significant Wave Height	P2 - Irregular Wave 1 Zero Crossing Period	P3 - Joint Forces Minimum Value	P4 - Joint Forces Maximum Value	Retain	Retained Data	Note
2	Units	m	s	N	N			
3	DP 0 (Current)	4	8	-9.1993E+05	6.4792E+05	☑	✓	
4	DP 1	4	10	-8.0702E+05	6.8507E+05	☐		
5	DP 2	3	9	-6.0664E+05	4.6574E+05	☐		
6	DP 3	3	11	-5.8628E+05	5.9277E+05	☐		
*						☐		

Results of Parameter Studies

You can also plot them from the Parameter Charts Toolbox:

- **Select Outline Of All Parameters to see the Toolbox**
- **Double-click on Parameters Chart**
- **Select X axis and Y axis parameters from Properties of Outline**

The resulting plot appears in Parameter Chart window (Note that line properties may be modified by RMB on the line and select Edit Properties)