Introduction to Hydrodynamic Analysis with Ansys Aqwa

Workshop 05.2: Hydrodynamic Analysis with Forward Speed

Release 2021 R2

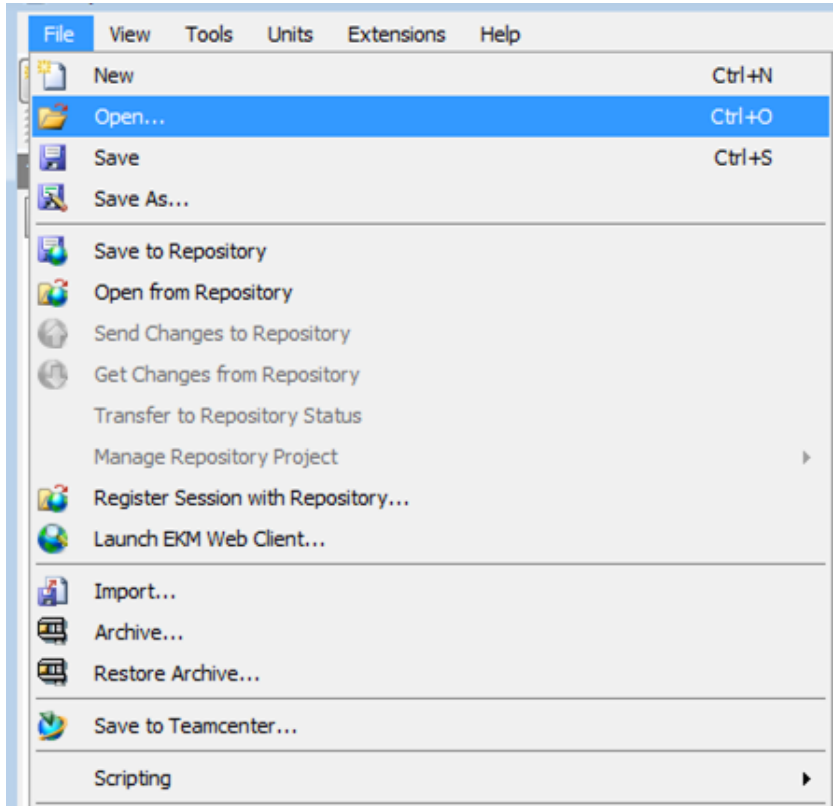
Forward Speed Simulation

- The goal of this workshop is to analyse a freely-floating vessel in the frequency and time domains, including corrections for forward speed effects.

<u>Open the Ship project previously created in Workshop 04.1</u>

Save As… to create another copy

Double-click on Model to open the Aqwa Workbench editor



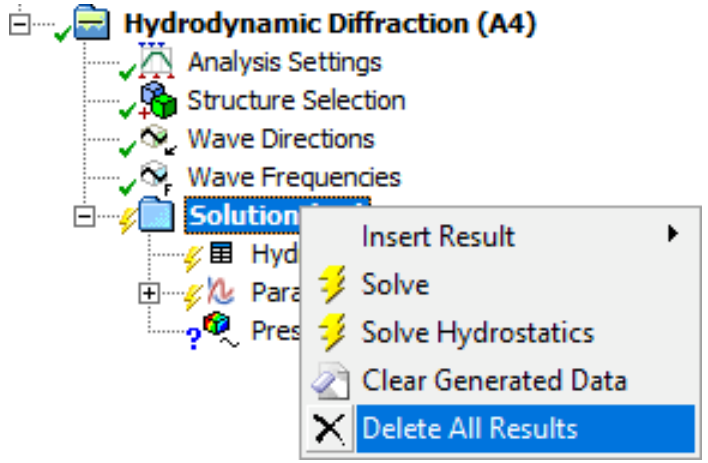
Analysis Settings

- We will start by re-calculating the hydrodynamic database to include forward speed corrections.
- In the Hydrodynamic Diffraction Analysis Settings, set:
  - Generate Wave Grid Pressures to No (to save calculation time)
  - Include Multi-Directional Wave Interaction to No (incompatible with forward speed analysis)

Details	
Details of Analysis Settings	
Name	Analysis Settings
External Operation before Solving	None
External Operation after Solving	None
Parallel Processing	Program Controlled
Generate Wave Grid Pressures	No
Common Analysis Options	
Ignore Modelling Rule Violations	Yes
Calculate Extreme Low/High Frequencies	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	
Source Strengths	No
Potentials	No
Centroid Pressures	No
Element Properties	No
ASCII Hydrodynamic Database	No
Example of Hydrodynamic Database	No
Generate AHD Pressure Output	No

Delete All Results

- The Pressures and Motions results are no longer valid, as we have turned off the Wave Grid Pressures calculation.
- We will add a new set or results objects for this analysis.
- On the Hydrodynamic Diffraction Solution, right-click > Delete All Results



Setting a Forward Speed

- Forward Speed options are defined in the Hydrodynamic Diffraction Wave Directions object.
- Set the Wave Directions Type to ‘Single Direction, Forward Speed’
- Set Forward Speed to 10 m/s (satisfies Fn < 0.3)
- Set Wave Direction to 150°

Details	
Details of Wave Directions	
Name	Wave Directions
Visibility	Visible
Type	Single Direction, Forward Speed
Forward Speed	10 m/s
Wave Direction	150°

- Click on Wave Frequencies
- Notice that the Wave Frequencies table now shows Encounter Frequencies

Details	
Details of Wave Frequencies	
Name	Wave Frequencies
Intervals Based Upon	Frequency
Incident Wave Frequency/Period Definition	
Range	Program Controlled
Total Number of Frequencies	10

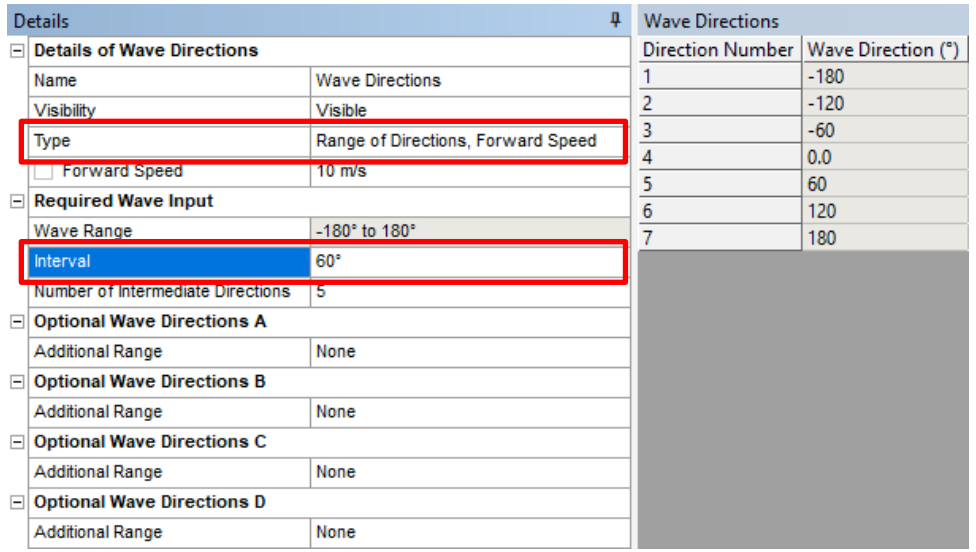
Encounter Frequencies	
Wave Frequency (Hz)	Encounter Frequency (Hz)
0.01592	0.01807
0.0415	0.05108
0.06709	0.09206
0.09268	0.14033
0.11826	0.19587
0.14385	0.25867
0.16944	0.32873
0.19502	0.40606
0.22061	0.49066
0.2462	0.58252

Setting a Forward Speed

- ‘Single Direction, Forward Speed’ may be sufficient if:
  - Any wave defined in a subsequent Hydrodynamic Response analysis is unidirectional

    AND
  - The relative wave heading will not change much in a time domain Hydrodynamic Response calc

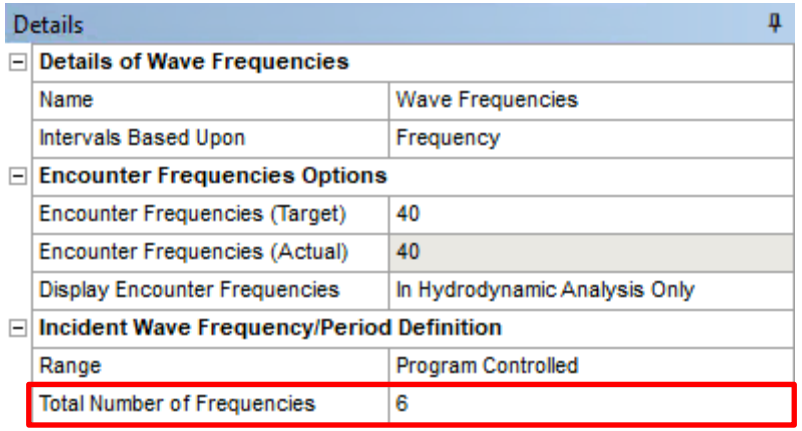
- We will use a **multi-directional wave spectrum** in the time domain, so click on Wave Directions again, and change the Type to ‘Range of Directions, Forward Speed’
- The number of encounter frequencies now depends on the number of wave directions. To reduce computation time, set the Wave Direction Interval to 60°



Setting for Encounter Frequencies

- Have another look at Wave Frequencies. You will see some new Details:
  - Encounter Frequencies (Target) – the number of encounter frequencies you would like to include in the analysis
  - Encounter Frequencies (Actual) – the number of encounter frequencies that will actually be included
  - Display Encounter Frequencies – controls what is displayed in the Table/Graph panel

- Reduce the **Total Number of Frequencies** to 6 (to reduce calculation time) – we will change the Encounter Frequencies in the next slide



Setting for Encounter Frequencies

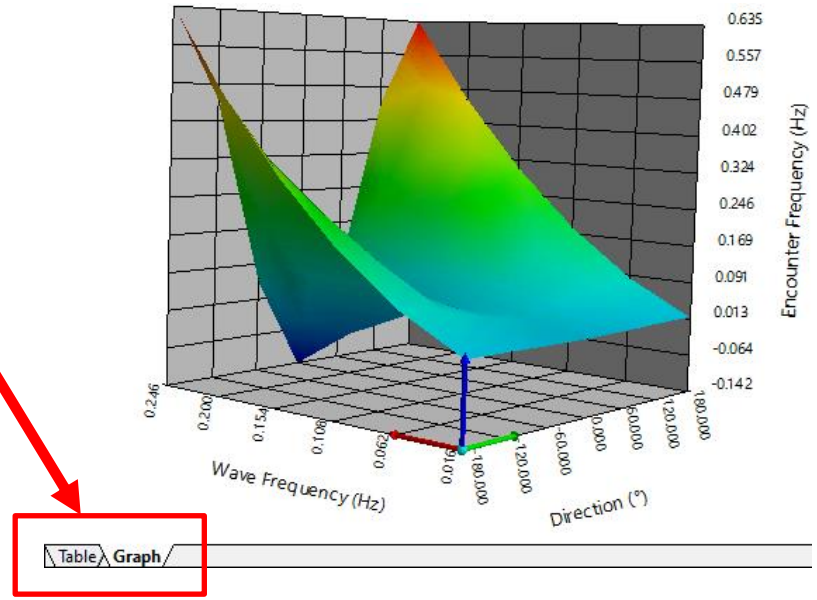
- Set Encounter Frequencies (Target) to 2
  - Encounter Frequencies (Actual) changes to 10 – this is the **minimum permissible** number of encounter frequencies for the defined Wave Directions and Wave Frequencies, according to the Aqwa solver
- Set Encounter Frequencies (Target) to 100
  - Encounter Frequencies (Actual) changes to 24 – this is the number of **unique** encounter frequencies based on the defined Wave Directions and (incident) Wave Frequencies
- Set Encounter Frequencies (Target) to 30, and leave it at this value
  - Encounter Frequencies (Actual) changes to 30 – the Aqwa solver will automatically distribute over the range of encounter frequencies

Setting for Encounter Frequencies

- While Display Encounter Frequencies shows ‘In Hydrodynamic Analysis Only’, the Table panel displays the encounter frequencies which will be included in the analysis.
- Change Display Encounter Frequencies to ‘For All Wave Frequencies and Directions’

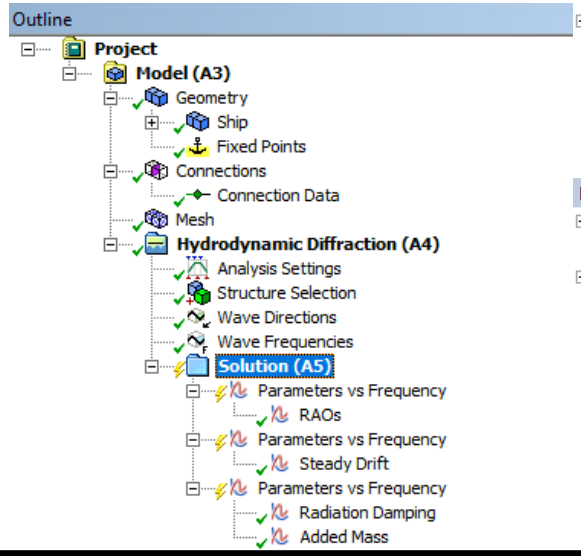
- The Table panel now displays encounter frequencies for each wave frequency/direction pair – note negative values
- Switch the bottom tab from ‘Table’ to ‘Graph’ to display a contour plot of encounter frequency vs wave frequency/direction

Encounter Frequencies for All Wave Frequencies and Directions							
Wave Frequency (Hz)	-180°	-120°	-60°	0.0°	60°	120°	180°
0.01592	0.0184	0.01716	0.01467	0.01343	0.01467	0.01716	0.0184
0.06197	0.08658	0.07427	0.04967	0.03737	0.04967	0.07427	0.08658
0.10803	0.1828	0.14541	0.07064	0.03326	0.07064	0.14541	0.1828
0.15408	0.3062	0.23014	0.07803	1.9683e-3	0.07803	0.23014	0.3062
0.20014	0.45678	0.32846	0.07182	-0.0565	0.07182	0.32846	0.45678
0.2462	0.63454	0.44037	0.05202	-0.14215	0.05202	0.44037	0.63454



Hydrodynamic Diffraction Results

- Add some graphical results to the Hydrodynamic Diffraction Solution:
  - Structure Motions > RAOs > Distance/Rotation vs Frequency, set Component to Global Z
  - Second Order Coefficients > Steady Drift > Force/Moment vs Frequency
  - Radiation Coefficients > Radiation Damping, set SubType to Global Z, Component to Global Z
  - On the 3rd 'Parameters vs Frequency' graph, right-click > Add Line > Radiation Coefficients > Added Mass, set SubType to Global Y, Component to Global Y
- Right-click Solution and **Solve**



Details

Details of RAOs	
Name	RAOs
Line Inputs	
Structure	Ship
Type	RAOs
Component	Global Z
Direction	-180°
Reference Point	Center of Gravity (Ship)
Motion Relative To	Origin of Fixed Reference Axes (FRA)

Details

Details of Steady Drift	
Name	Steady Drift
Line Inputs	
Structure	Ship
Type	Steady Drift
SubType	Near Field
Component	Global X
Direction	-180°

Details

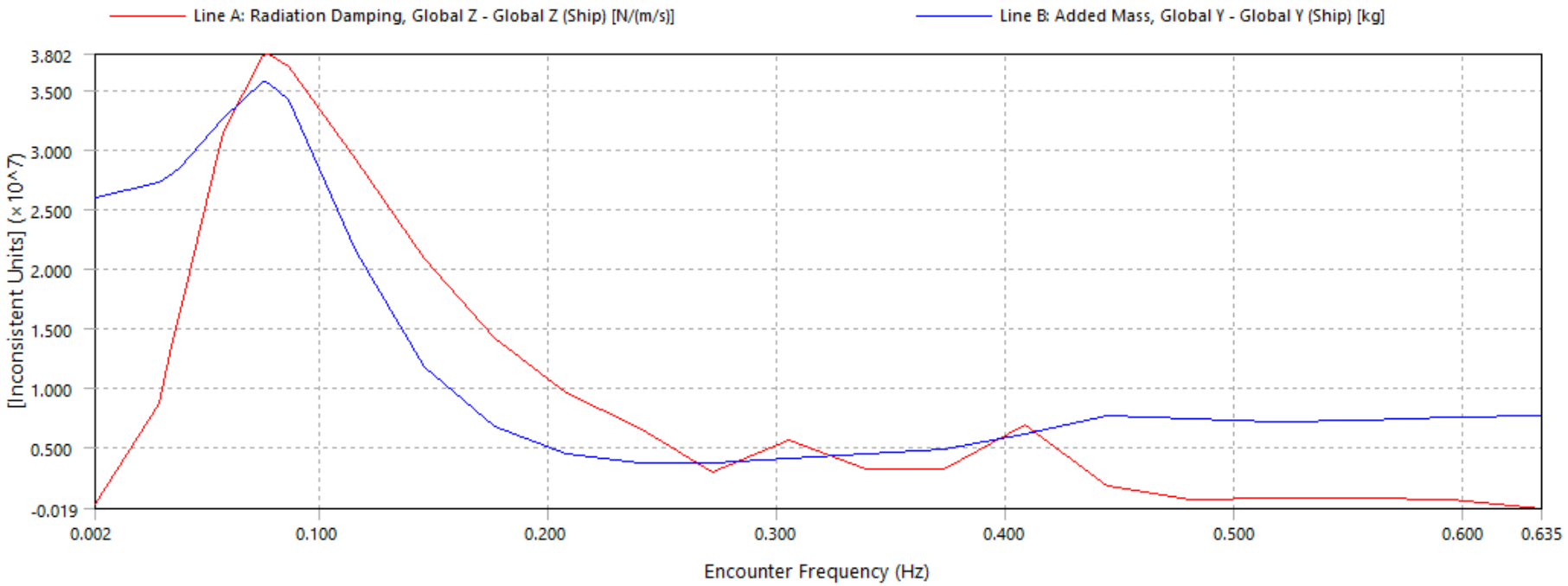
Details of Radiation Damping	
Name	Radiation Damping
Line Inputs	
Structure	Ship
Type	Radiation Damping
SubType	Global Z
Component	Global Z

Details

Details of Added Mass	
Name	Added Mass
Line Inputs	
Structure	Ship
Type	Added Mass
SubType	Global Y
Component	Global Y

Review Results

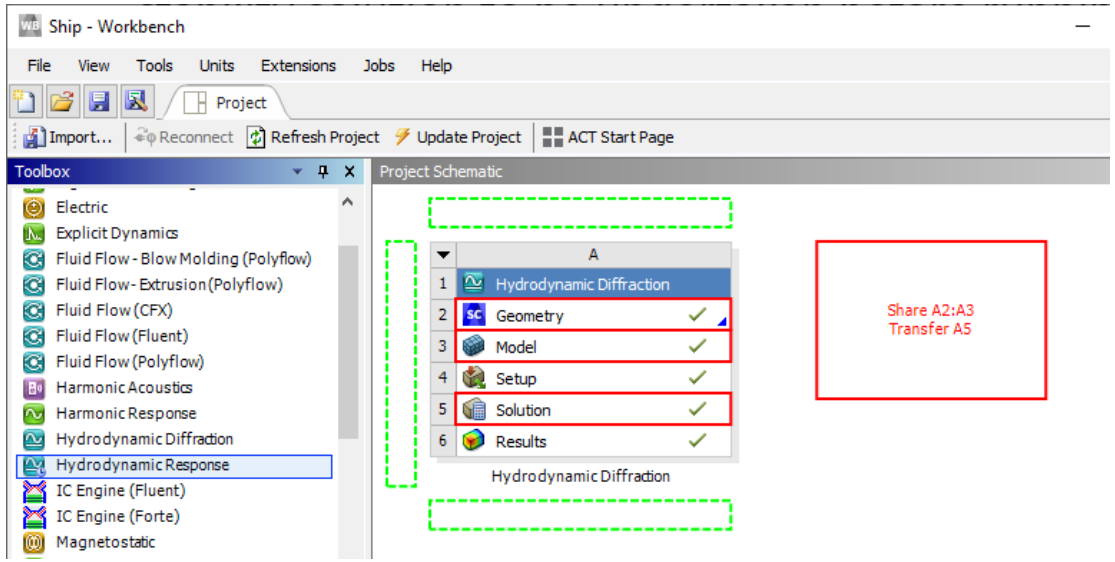
- RAOs and drift coefficients are reported vs Wave Frequency/Direction
- Radiation Damping and Added Mass are reported vs **Encounter Frequency**

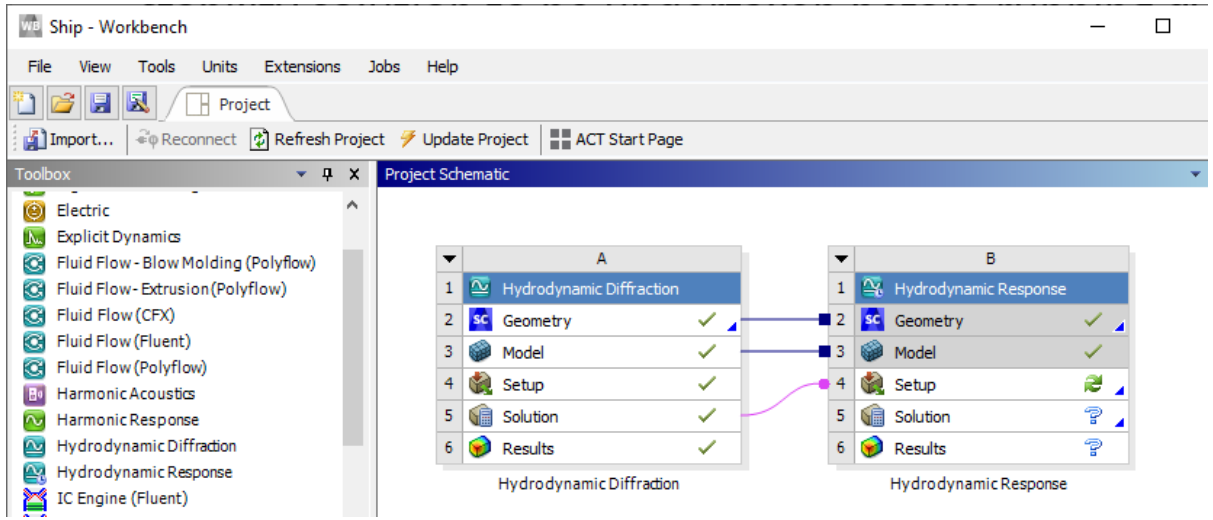


- **Save the project** once the Hydrodynamic Diffraction Solution is up-to-date

Adding the Stability Analysis HR System

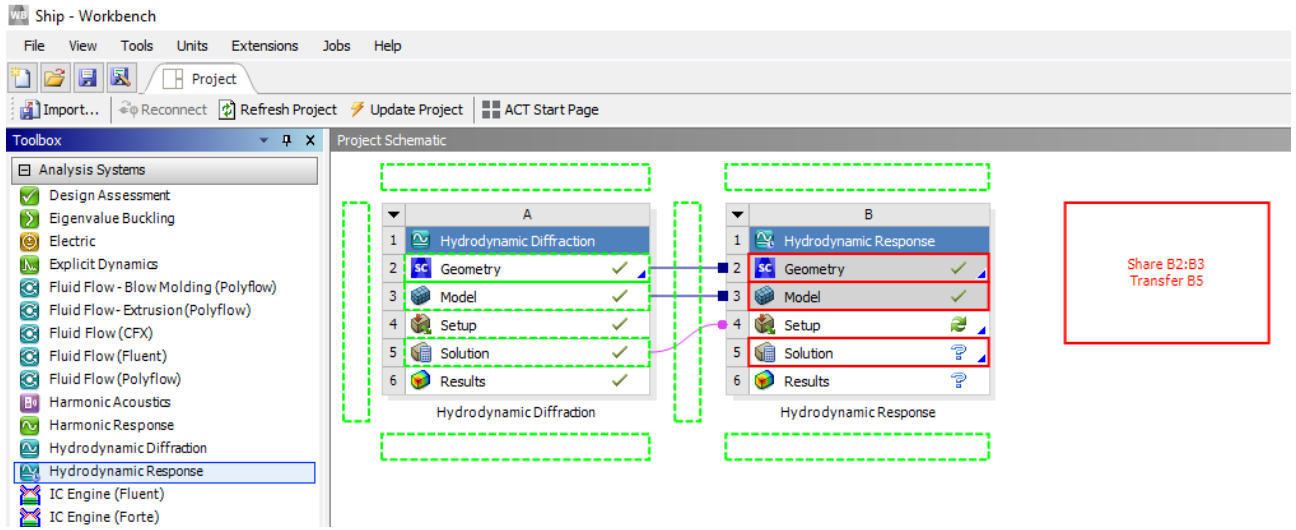
- Drag and drop a Hydrodynamic Response system on to the Project Schematic, sharing the solution from Hydrodynamic Diffraction. This will become the Static Stability Analysis, which should be undertaken before running dynamic simulations.





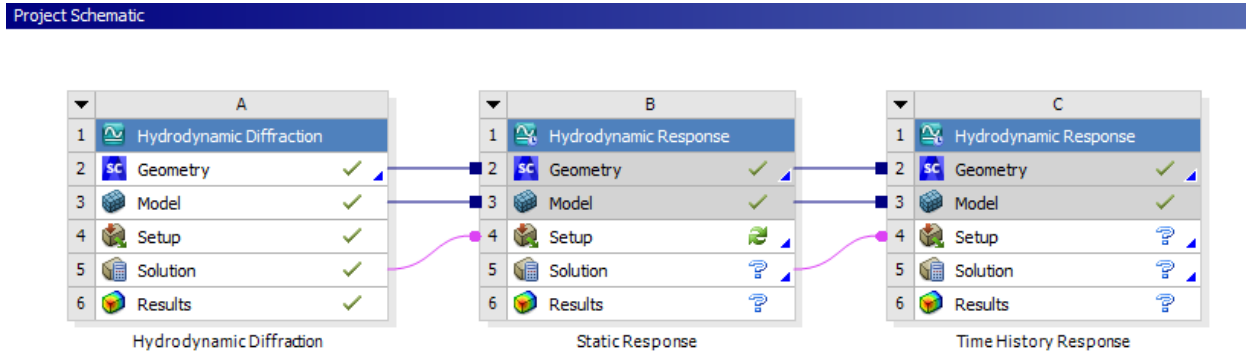
Adding a Time Response HR System

- A second Hydrodynamic Response system is added for the time domain analysis



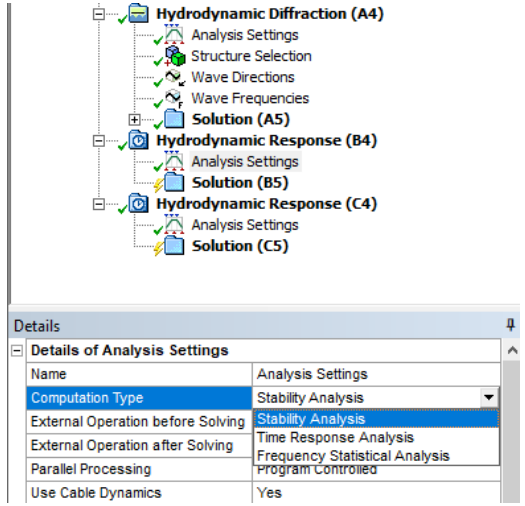
Drag and drop the new HR system on to the Solution cell of the existing HR system. Note that we can rename the systems by right-clicking on the system header and selecting Rename.

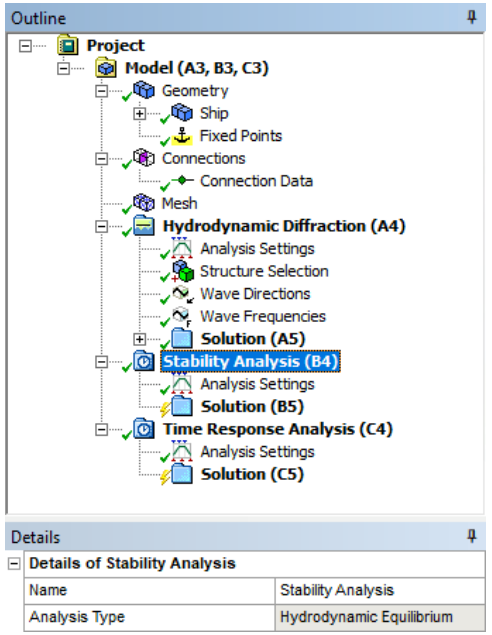
- Go back to the Aqwa Workbench editor.



Set up Static Stability Response System

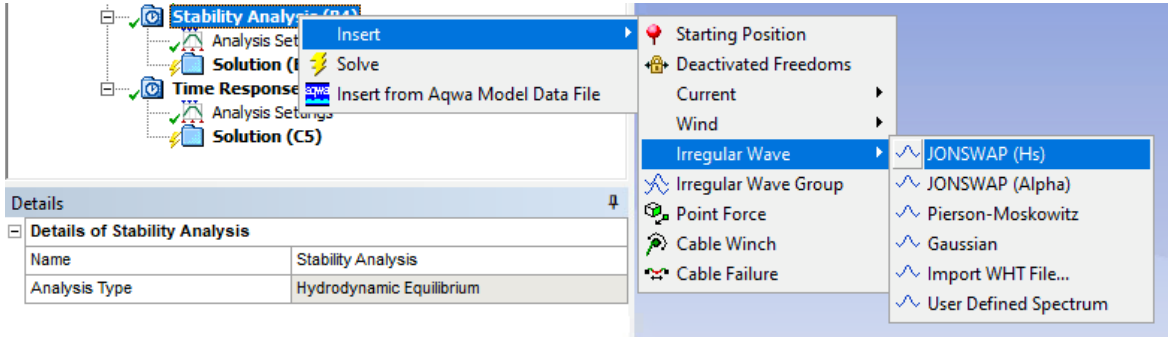
- In the Outline tree, under the Analysis Settings of Hydrodynamic Response (B4), check that the analysis type is set as Stability Analysis (this is the default when the upstream system is a Hydrodynamic Diffraction analysis).
- This will allow us to determine a realistic starting position for the structure, to be used as the initial conditions for the time domain analysis.
- Rename this analysis system to Stability Analysis, by selecting the Hydrodynamic Response (B4) item in the tree and changing the Name in the Details panel.
- Repeat for the Time Response Analysis (C4).





Define the Environment

- Right-click on Stability Analysis, and Insert > Irregular Wave > JONSWAP (Hs)
- Set Wave Range Defined By to Period
- Set Direction to 150°



- Set Wave Spreading to ‘Nth-Powered Cosine’
- Set Omit Calculation of Drift Forces to Yes
  - Drift coefficients may be inaccurate for simulations including forward speed – pulsating source distribution in Hydrodynamic Diffraction calc (not translating-pulsating)
- Set Significant Wave Height to 3 m
- Set Gamma to 3.3
- Set Peak Period to 11 s

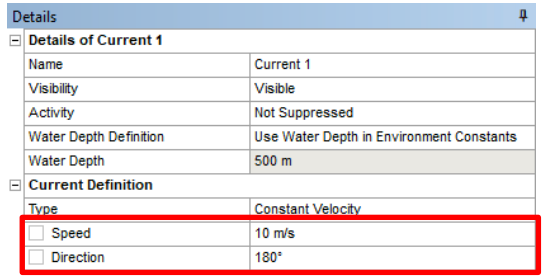
Details

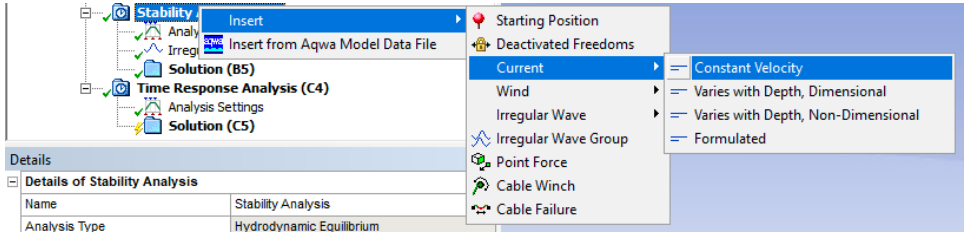
Details of Irregular Wave 1	
Name	Irregular Wave 1
Visibility	Visible
Activity	Not Suppressed
Wave Range Defined By	Period
Wave Spectrum Details	
Wave Type	JONSWAP (Hs)
Direction of Spectrum	150°
Wave Spreading	Nth-Powered Cosine (Short-Crested Waves)
Power of Spreading Function	2
Total Spreading Angle	180°
Number of Sub-Spectra	7
Spectrum Presentation Method	2D Spectrogram (Linear)
Seed Definition	Program Controlled
Number of Spectral Lines Definition	Program Controlled
Omit Calculation of Drift Forces	Yes
Start and Finish Period Definition	Program Controlled
Start Period	18.76965 s
Finish Period	2.72885 s
Significant Wave Height	3 m
Gamma	3.3
Peak Period	11 s
Export CSV File	Select CSV File...
Cross Swell Details	
Wave Type	None

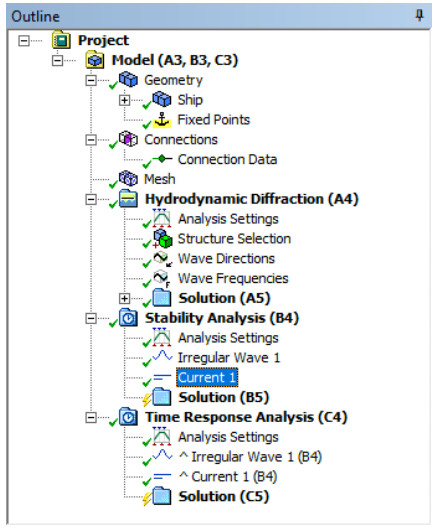
Define the Environment

- For a simulation including forward speed in the time domain, we should either:
  - Move the vessel through the water
  - Move the water under the vessel (usually easier)
- For the second option, we define a Current with velocity opposite to the vessel velocity.

- Right-click on Stability Analysis, and Insert > Current > Constant Velocity
- Set Speed to 10 m/s
- Set Direction to 180°







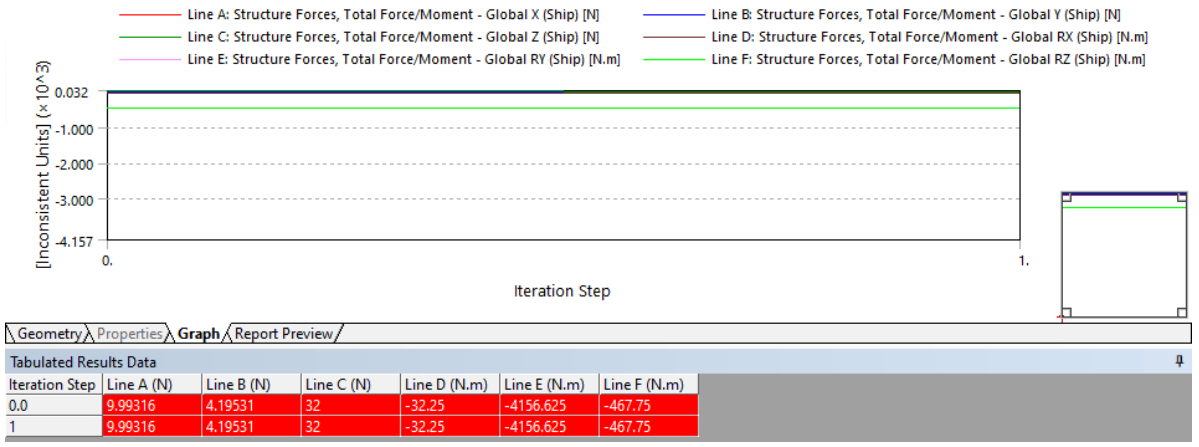
- Right-click and **Propagate** on both Irregular Wave 1 and Current 1, so that the environment in the Time Response Analysis is consistent with the Stability Analysis

Solve the Stability Analysis

- Right-click on the Stability Analysis Solution and **Solve**.

- The convergence to equilibrium is immediate – there are no unbalanced static forces acting on the vessel:
  - Current 1 only affects a structure if that structure includes Morison elements, and/or has Current Force Coefficients defined
  - Irregular Wave 1 exerts only dynamic (wave frequency) forces – drift forces have been turned off

- You can check this for yourself by including Structure Forces > Total Force/Moment plots for each of the 6 degrees of freedom.



Iteration Step	Line A (N)	Line B (N)	Line C (N)	Line D (N.m)	Line E (N.m)	Line F (N.m)
0.0	9.99316	4.19531	32	-32.25	-4156.625	-467.75
1	9.99316	4.19531	32	-32.25	-4156.625	-467.75

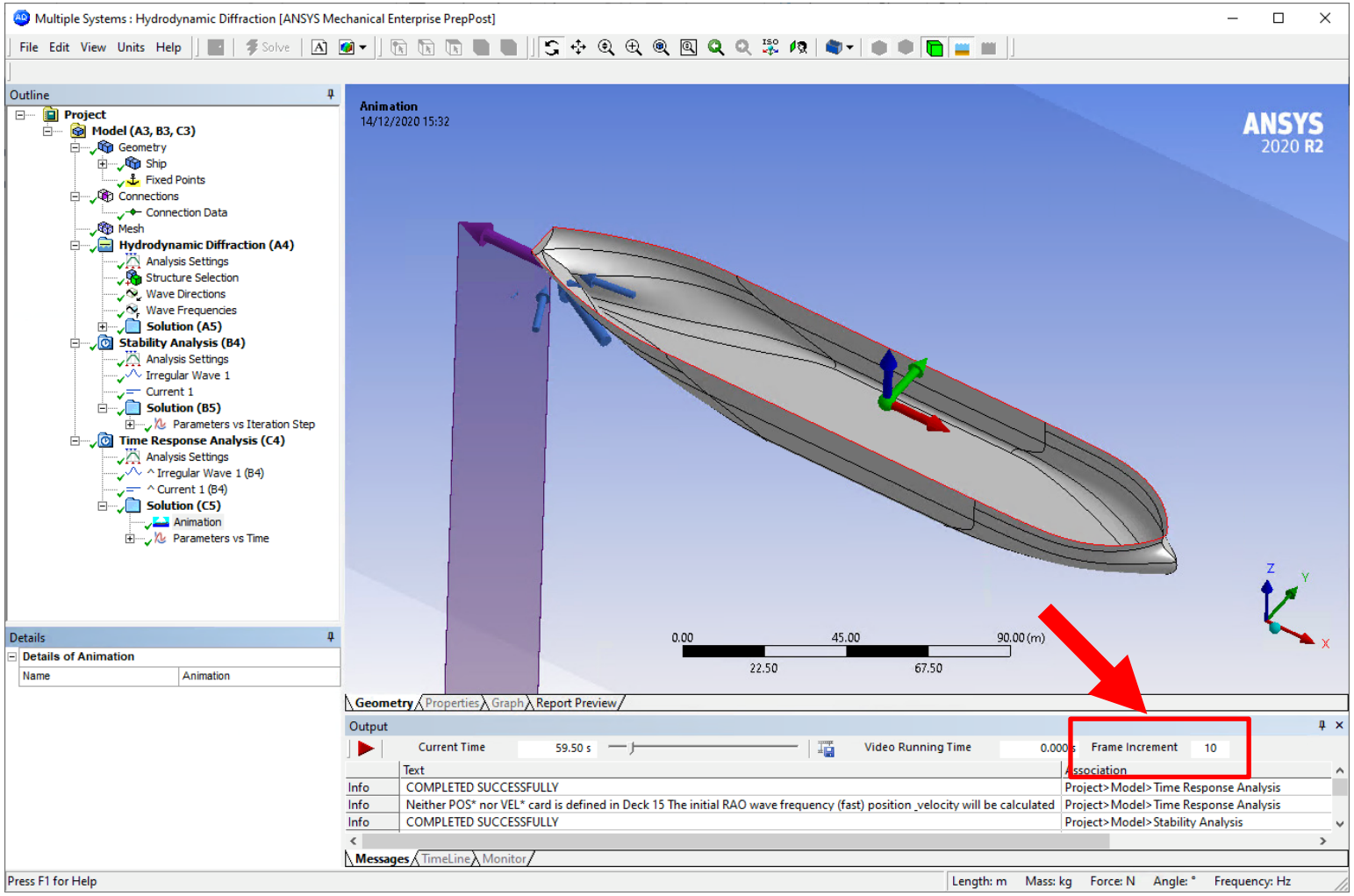
Time Response Simulation Options

- Go to Time Response Analysis > Analysis Settings
- Leave Analysis Type as Irregular Wave Response with Slow Drift (but drift forces are still turned off)
- Set Output Step to 0.5 s to reduce output file size
- Set Duration to 600 s
- Notice the option **Account for Current Phase Shift** – this will automatically modify the Irregular Wave frequencies to account for the effect of the Current. This is set to 'Yes' by default.
- Right-click on the Time Response Analysis Solution and **Solve**.

Details	
Details of Analysis Settings	
Name	Analysis Settings
Computation Type	Time Response Analysis
External Operation before Solving	None
External Operation after Solving	None
Parallel Processing	Program Controlled
Use Cable Dynamics	Yes
Time Response Specific Options	
Analysis Type	Irregular Wave Response with Slow Drift
Start Time	0.0 s
Time Step	0.1 s
Output Step	0.5 s
Duration	300 s
Number of Steps	3001
Finish Time	300 s
Starting Position	Determined by Upstream System
X-Position for Wave Surface Elevation Output	0.0 m
Y-Position for Wave Surface Elevation Output	0.0 m
Common Analysis Options	
Convolution	Yes
Call Routine "user_force"	No
Connect to Server for External "user force" Calculation	No
Calculate Motions Using RAOs Only	No
Account for Current Phase Shift	Yes
Apply Drift Force with Multi-Directional Wave Interaction	No
Calculate Wave Drift Damping	Yes
Include Yaw Wave Drift Damping	Yes
Use Slow Velocity for Hull Drag Calculation	No
QTF Options	
Use Full QTF Matrix	No
Use Sum Frequency QTFs	No
Output File Options	
Axis System for Joint Reactions	Fixed Reference Axes
Data List	Yes
Element Properties	No
Dynamic Cable/Tether Drag	No

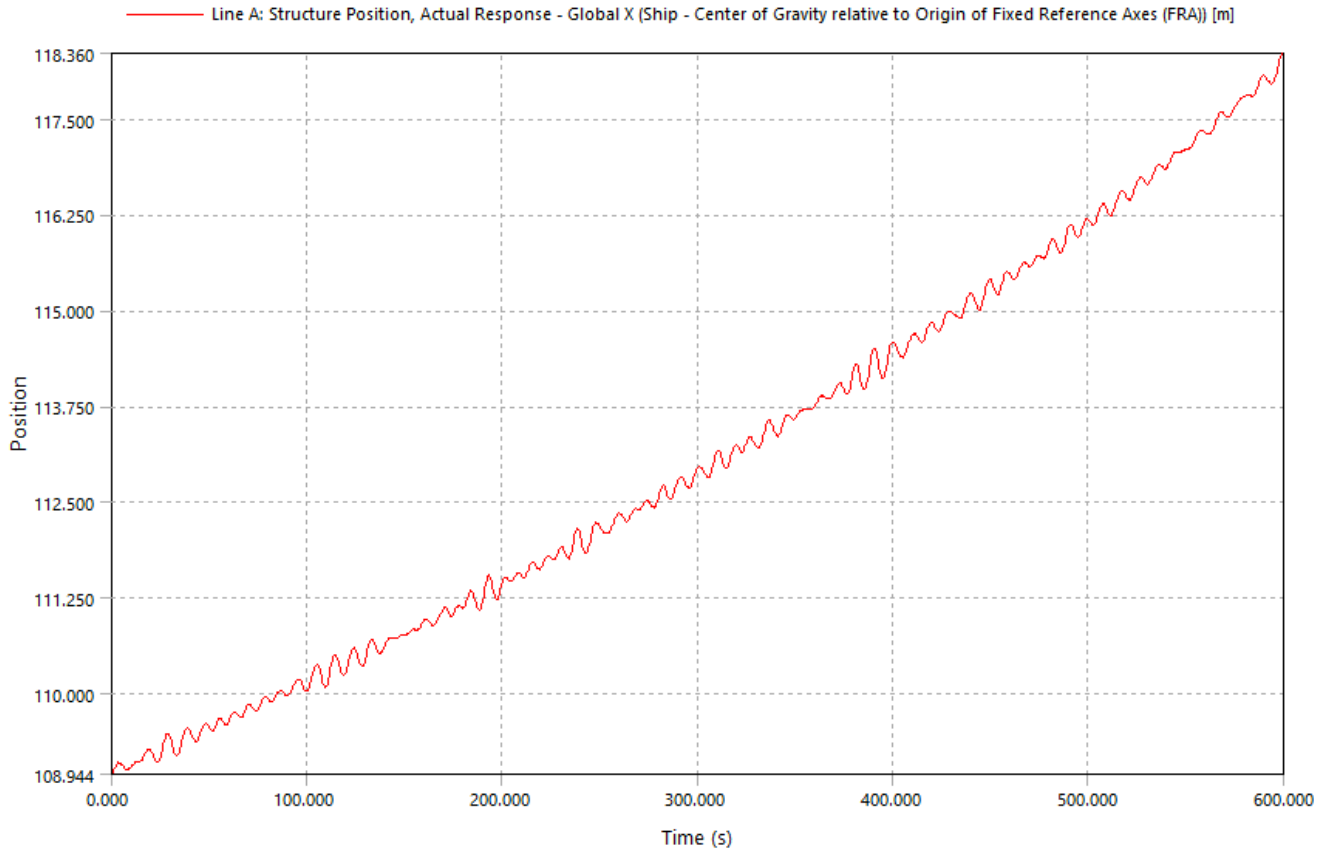
Check the Solution

- Right-click on Solution and Insert Result > Animation
- The animation frames will be shown at 0.5-second intervals (based on Output Step)
- Set the Animation Frame Increment to 10, so that the playback is accelerated to 5 seconds per frame



Check the Solution

- Right-click on Solution and Insert Result > Structure Motions > Structure Position > Actual Response. Set the Component to display the vessel Global X position



Restricting Vessel Motions

- To remove the resultant X motion, we can:
  - Add soft mooring lines – linear Cables with low stiffness to hold the vessel in place – try this for yourself
  - Add Deactivated Freedoms – objects created in the time domain analysis which simply turn off vessel motions in selected freedoms
  - Define a dynamic positioning system (DPS) to hold the vessel in position

- **Save your Workbench project** so that we can add a PID controller to the model, acting as a simple DPS, later on in the course