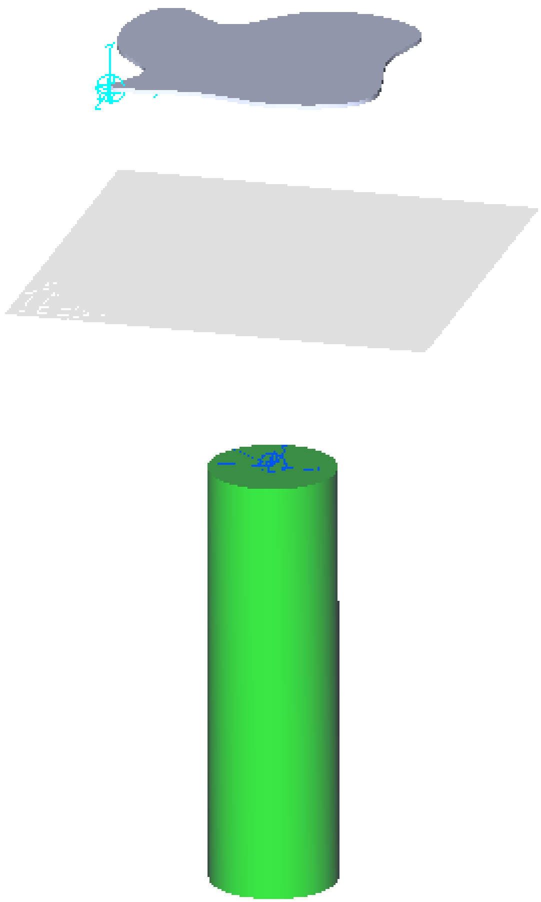
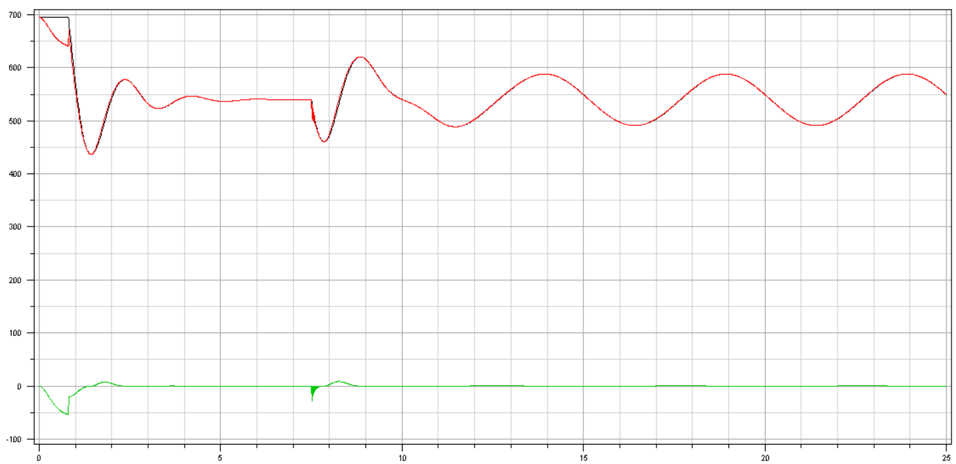
Tutorial
Buoyant Cylinder





Tutorial Overview

FEDEM is a comprehensive modern CAE tool for virtual testing and verification of mechanical systems. The integrated use of dynamics and structural solving in FEDEM is an exceptionally efficient way of analyzing mechanisms.

This tutorial will introduce some of the capabilities FEDEM has with respect to dynamic motion solving. The purpose of this tutorial is to introduce the user to a simple dynamic problem that can be solved without the use of FE models. Other tutorials will show how this dynamic motion is integrated with the solving of FE Models.

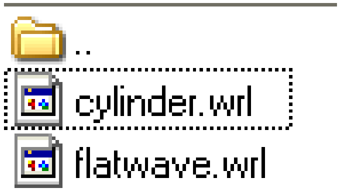
Before Starting

Limited experience or prerequisite training is required to complete this tutorial. However, the tutorial is aimed at someone with elementary understanding of physics and computer applications.

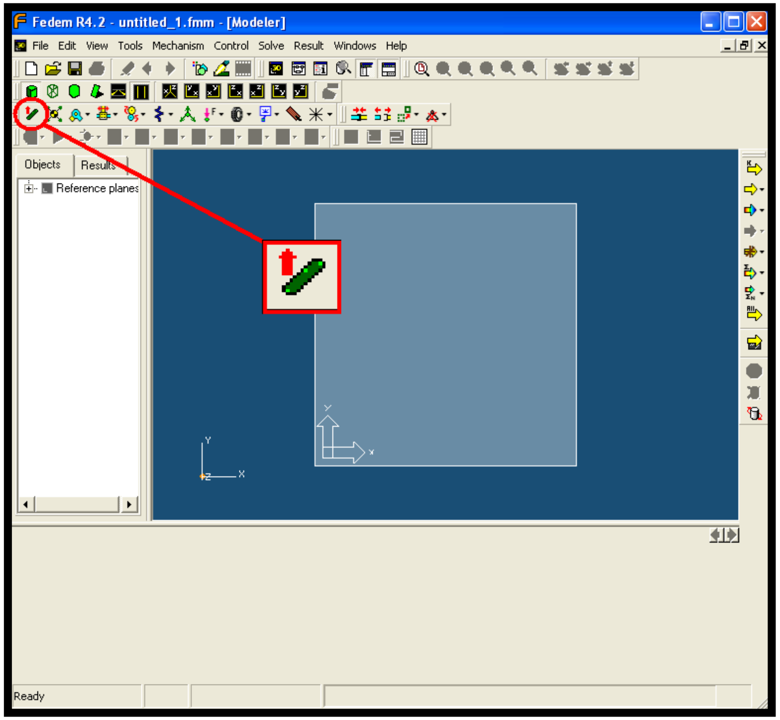
- Download the newest FEDEM Release
- Download the folder containing the parts necessary for this tutorial
  - www.fedem.dom\ettellerannet

Importing Parts

1. Open FEDEM and select the load link symbol
2. Enter the directory where the files are located (Parts downloaded from ….Link…..)
3. Use the Ctrl key and select all parts. A List of the parts that should be in your directory is shown below (make sure to select ''all files' in the file type drop down menu. The files used in this case are .wrl)

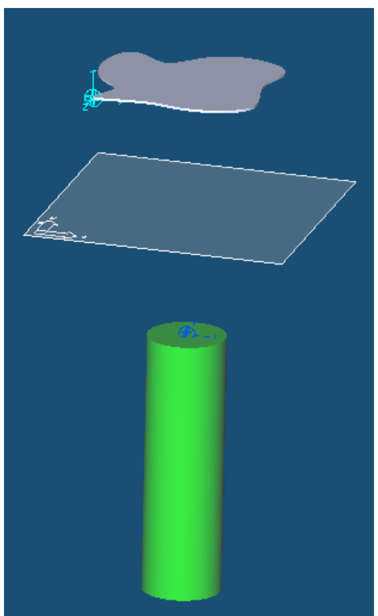


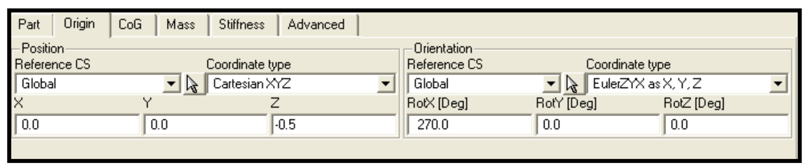
4. Open

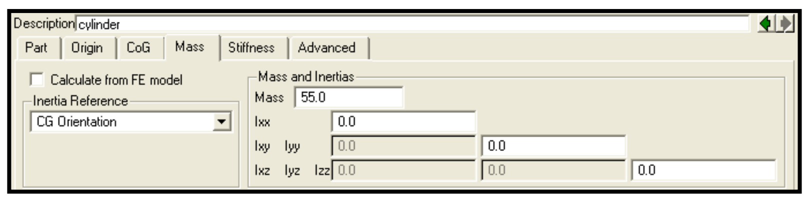


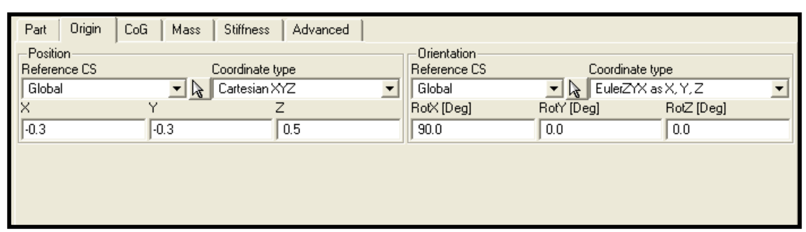
Orientating links

1. Select the cylinder by left clicking on the object. The Property Manager will then appear at the bottom of the screen.
2. Open the ”Origin” tab in the Property Manager and change the following: Z=-0.5 ,”RotX[Deg]” = 270.
3. Open “Mass” tab in the same manager and set the mass property to 55
4. Change the following position and orientation for the plate as previously demonstrated. X=-0.3 , Y-0.3, Z=0.5, RotX[Deg]=90
5. The model should now be aligned and appear as shown below.





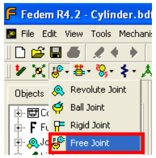


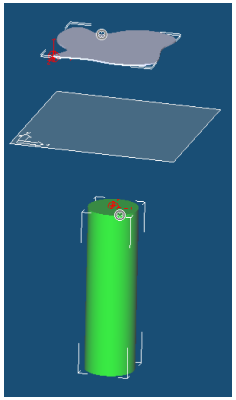


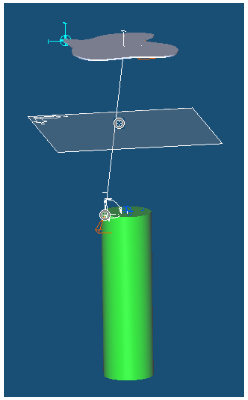
Applying Free Joints

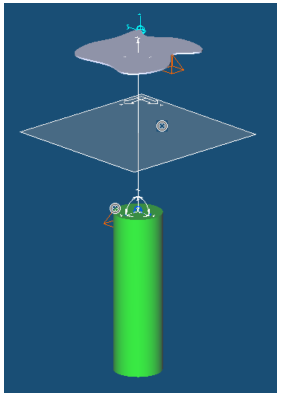
In order to relate the links to each other they have to be connected by the use of a joint. In this case the motion of the cylinder will be restricted to the vertical axis (wit respect to the workplane, z-axis)

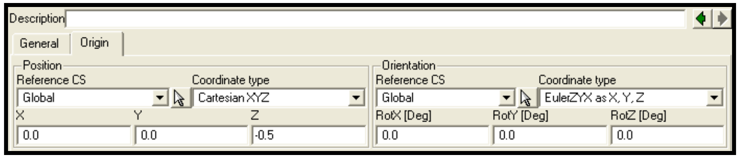
1. Select free joint from the dropdown menu in the toolbar
2. Select the plate (flatwave) Done/Enter
3. Select the Cylinder Done / Enter
4. For visual reasons- select the coordinatsystem that appears at the end of the free joint that was just applied. In the Property Manager change the following: (for cylinder joint, x=0, y=0, z=-1, For flatwave joint, x=0, y=0, z=0.5)

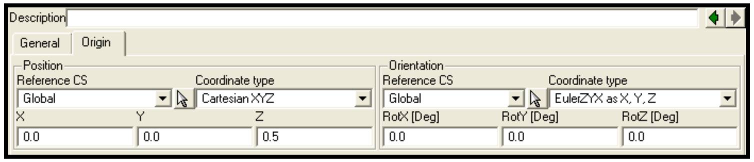




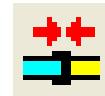






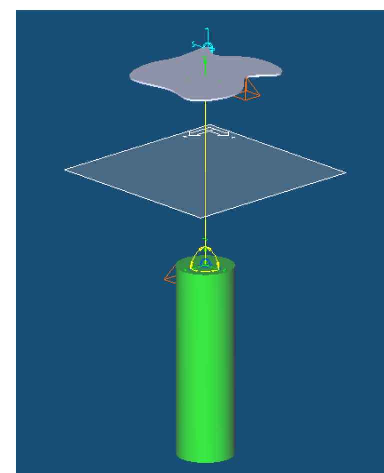


Attaching Free Joints

1. Use the attach option from the toolbar 
2. Select the coordinatsystem of the joint (on wave), Done/Enter
3. Select flatwave, Done/Enter. (This will make the plate the master)
4. Select the joint cooridnatsystem closest to cylinder Done/Enter
5. Select the cylinder Done/Enter (This will now make the cylinder the slave)

   The joint should now appear yellow (green coordinates)
6. Select the joint so that the Property Editor appears. (make sure to select the actual joint and not the coordinate systems). Set all except Tz to fixed
7. Set Tz to ‘’Spring – Damper’’
8. Set the damper properties (Property Manager)

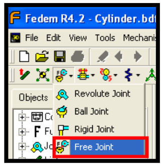
   to 100

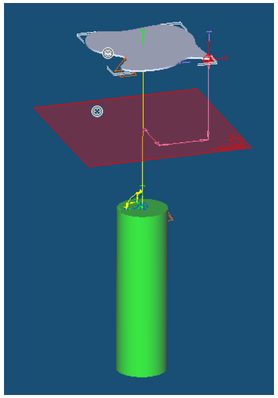


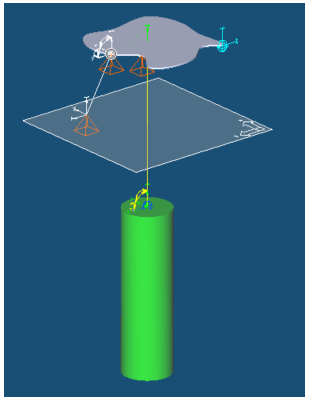
Applying Free Joints

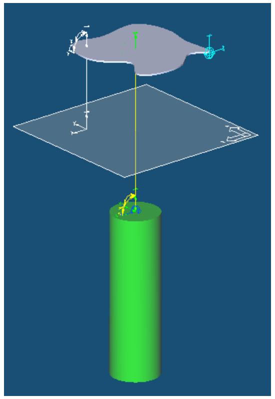
Now that the cylinder is linked to the plate and can move relative to the ”wave”, it is time to repeat the process so that the wave can move relative to the workplane.

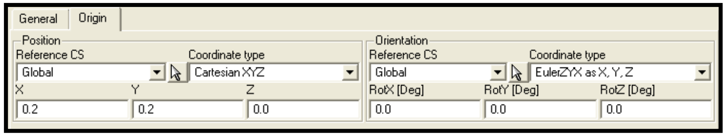
1. Select free joint from the dropdown menu in the toolbar
2. Select the workplane Done/Enter
3. Select flatwave Done / Enter
4. For visual purposes- select the coordinatsystem that appears at the end of the previously applied free joint. In the Property Manager change the following: (for workplane joint, x=0.2, y=0.2, z=0,for flatwave joint, x=0.2, y=0.2, z=0.5)

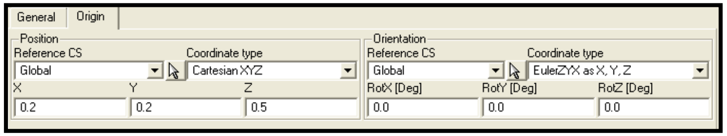








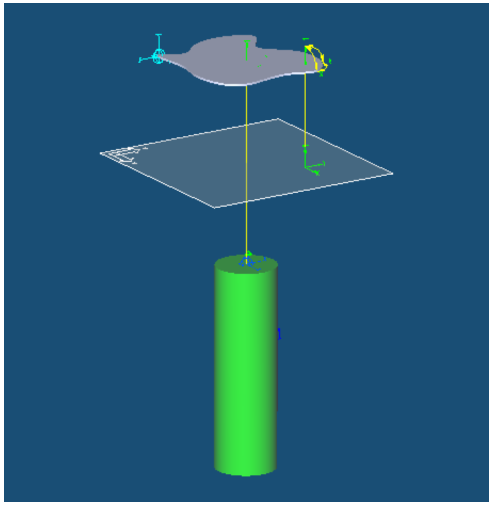




Attaching Free Joints

1. Use the attach option from the tool bar menu.
2. Select the coordinatsystem of the joint (on workplane), Done/Enter
3. Select the workplane, Done/Enter. (this will now become the master)
4. Select the joint cooridnatsystem closest to flatwave Done/Enter
5. Select flatwave Done/Enter (this will then become the slave)

   The joint should now appear yellow (green coordinates)
6. Click on the joint so that the Property Editor apears. (make sure to select the actual joint and not the coordinate systems). Set all to fixed



In simple terms this exercise will illustrate the motion of a cylinder that is pulled under water to an arbitrary depth. The cylinder will then be released and plunge to the surface where it will stabilize after some oscillating motion. After some time a function controlling the motion of the plate (wave) will initiate and we will observe the motion of the cylinder with respect to the motion of the simulated wave.

There are several forces acting on the cylinder under the different stages of its oscillating motion. In this exercise theses are somewhat simplified. The forces included in this simulation are as following.

1. Buoyancy force (function)
   - Changing with respect to how much of the cylinder is submerged
2. Drag (3 components, Output from Control Editor)
   - Drag due to skin friction. Varying with submerged area
   - Drag due to top surface. Only relevant when the cylinder is completely submerged and moving towards the surface
   - Drag due to bottom surface. Only relevant when cylinder is in water and moving vertically down from the surface

Buoyancy

FEDEM

$$F(x)=mg-(\rho * g * V * l(x))$$

Where:

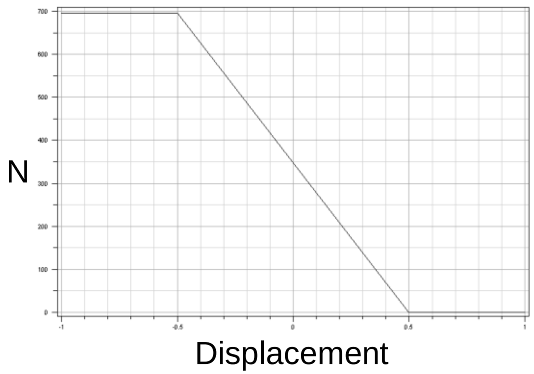
mg - Mass acceleration. Not needed in function whereas it is built in to the FEDEM Software

g - Gravitational acceleration 9.81 m/s^2

V - Total volume of cylinder = $V=\pi r^2 L=\pi\times 0.15^2\times 1=0.071m^3$

l(x) - Linear function describing the amount of the cylinder that is submerged with respect to the displacement of the free joint connected between the cylinder and plate (flatwave)

F(x)=1000*9.81*0.71*l(x) = 695 l(x)

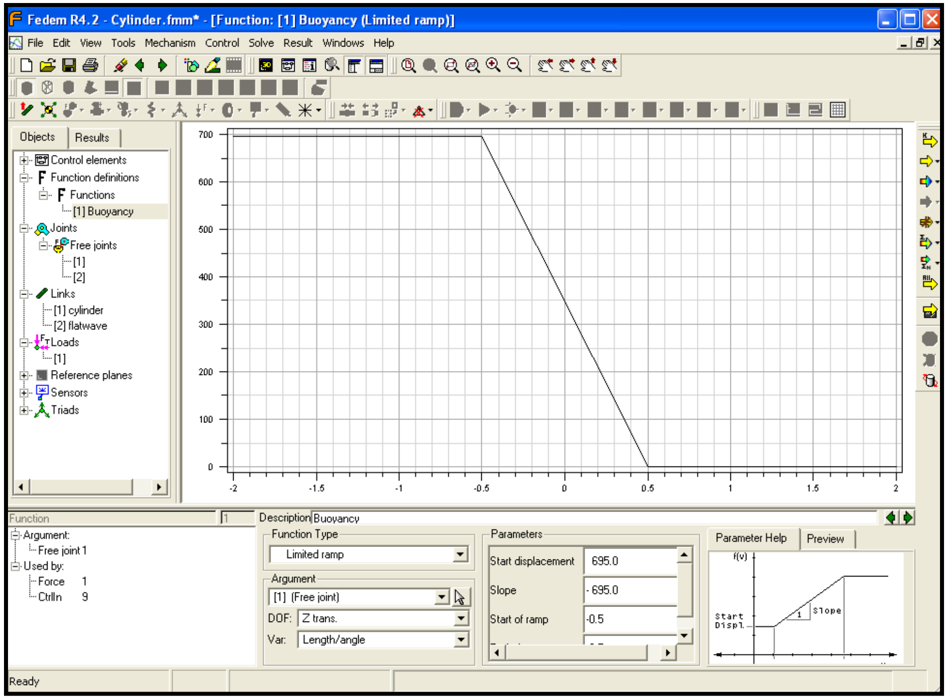


Creating the function

1. Right click in the Model Manager and select create – function
2. Give the function the description – Buoyancy
3. Select ''limited ramp'' as the function type
4. ''Argument'' (click the small harrow next to the drop down window and select the joint that is connecting the cylinder to flatwave) Done / Enter
5. DOF- ''Z trans'' (Which is in the direction of the motion)
6. Insert the following parameters

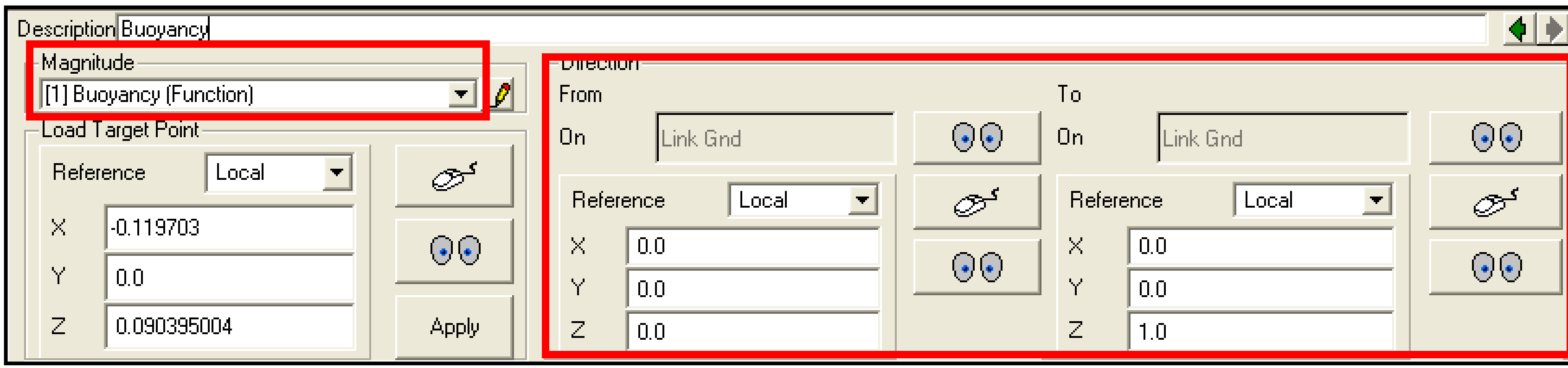
   Start displacement = 695
   Slope = -695
   Start of ramp = -0.5
   End of ramp = 0.5

7. Var: [Length/amgle]



Applying buoyncy

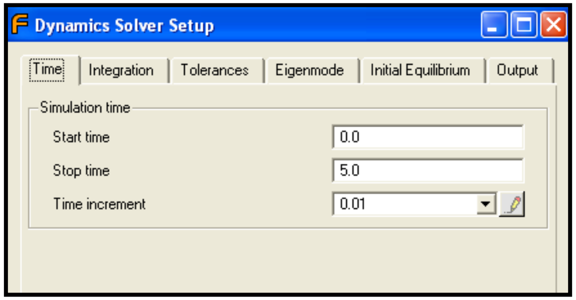
1. Apply a load to the cylinder by selecting  from the toolbar
2. Select the cylinder
3. Select the force in the Model Manager, and change the following parameters in the Property Manager (marked in red)



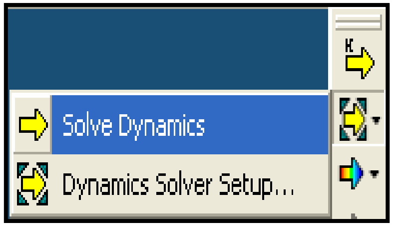
1. Enter

Run Simulation

Enter the dynamics solver setup and change the stop time to 5 sec (1 sec default)

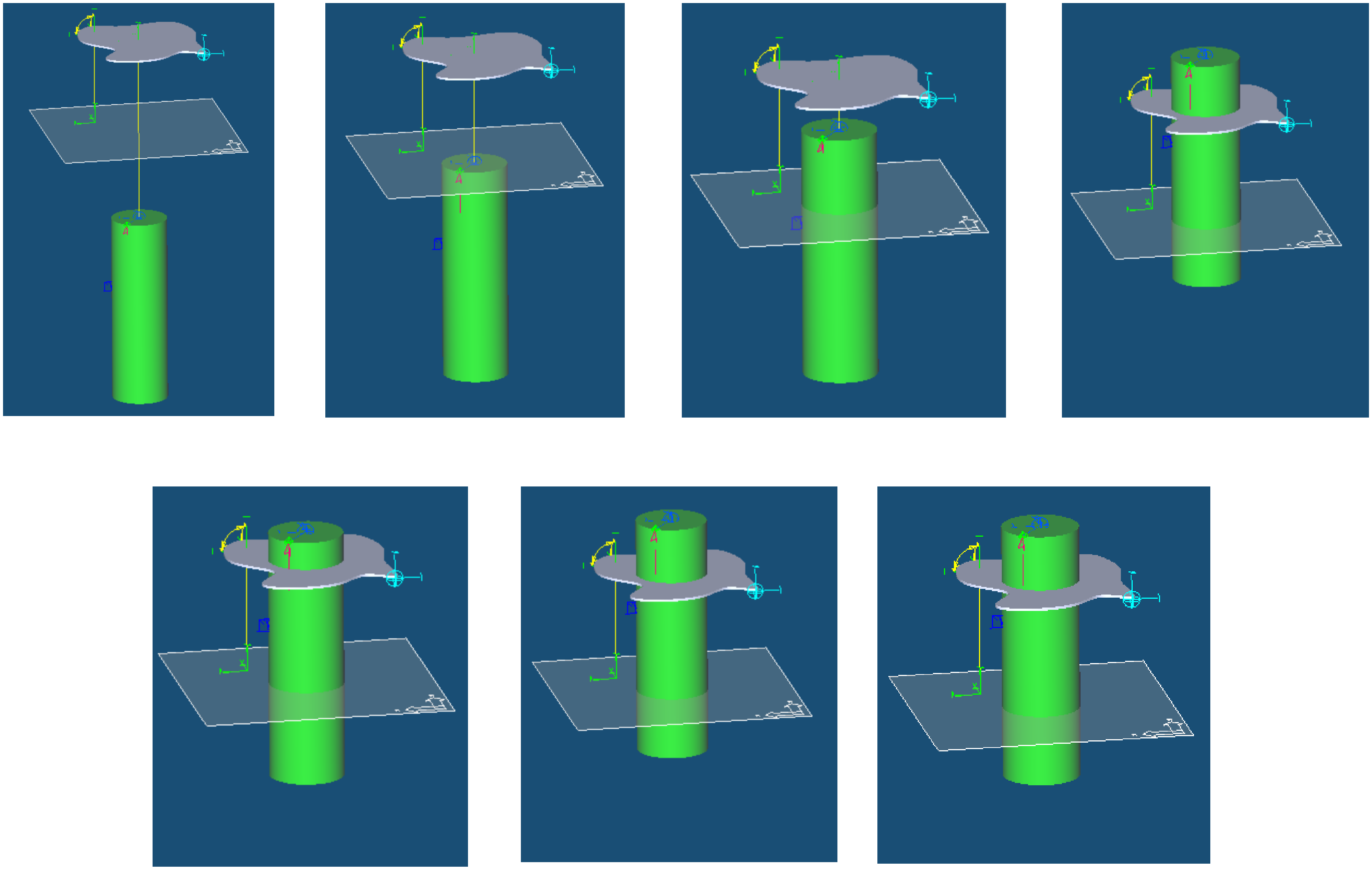


Now run the simulation by clicking the solver button located on the far left side on the FEDEM interface



When the computer has solved the dynamics, enter the result tab in the Model Manager. Expand the animations tree and right click on the dynamics [rigid body motion] option. – Load Animation. It is now possible to view the animation by using the control that appears in the bottom left corner of the screen.

Result



Adding Drag Friction Force

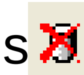
The total drag force is determined by the following equations:

$$Fd = \left(\frac{1}{2} C_{Flat} \rho V^2 A_{Flat}\right) + \left(\frac{1}{2} C_{Skin} \rho V^2 A_{Skin}\right)$$

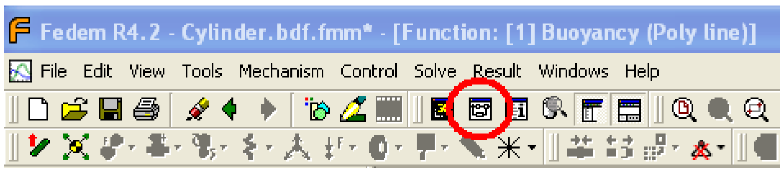
Where C is the drag coefficient for the relevant part. The friction coefficients are assumed to be 1.2 and 0.05 for the flat area perpendicular to the motion and parallel to the motion respectively. This is an approximation and is only suitable for this exercise.

The first section of the equation will change dependent on whether the cylinder top/bottom is submerged and is moving towards or from the surface. It is therefore imperative to create functions that describe the position and motion of the cylinder.

Control Editor

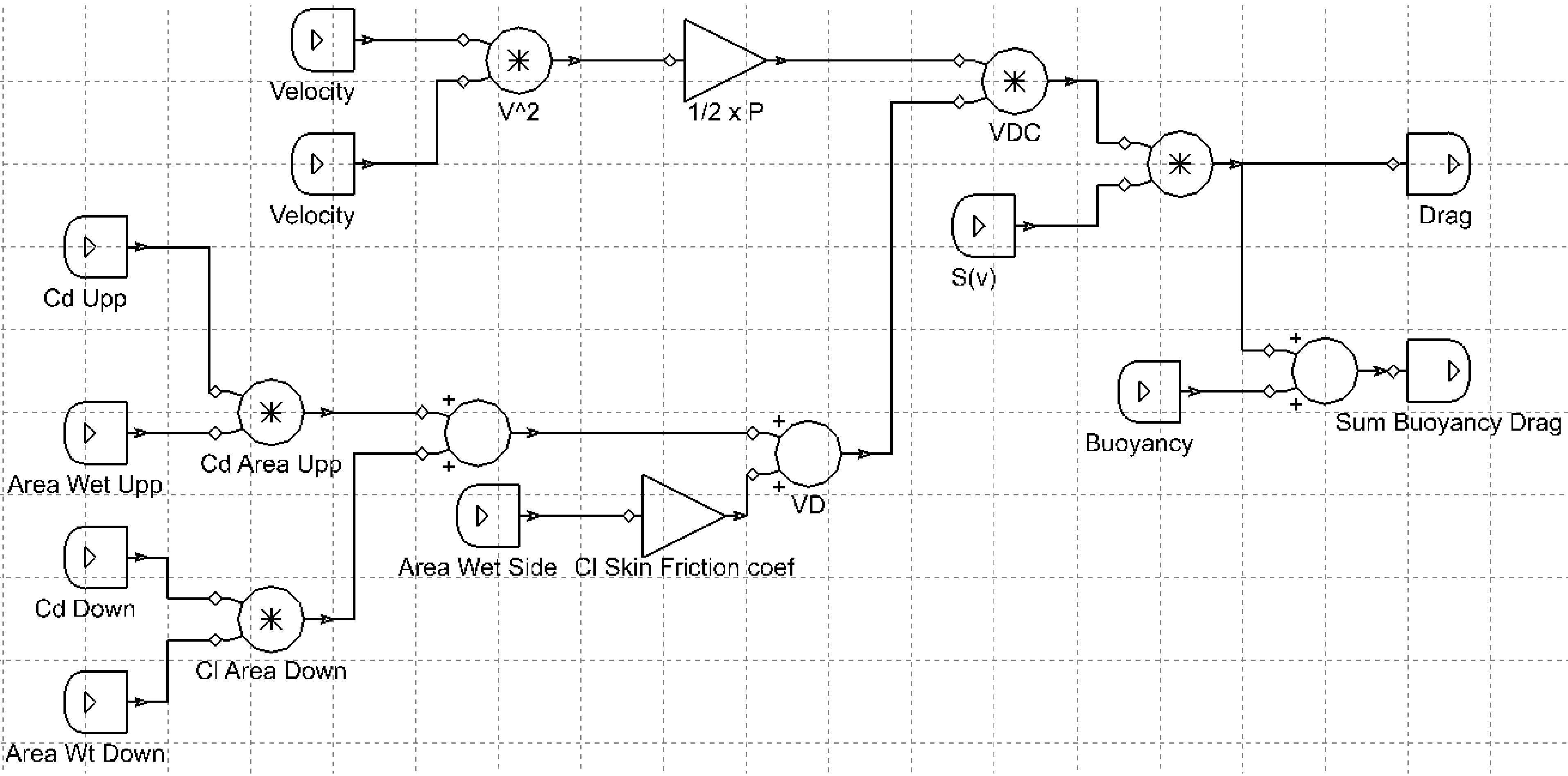
Delete the solution obtained previous 

Open the control editor by selecting the button located on the toolbar as indicated below



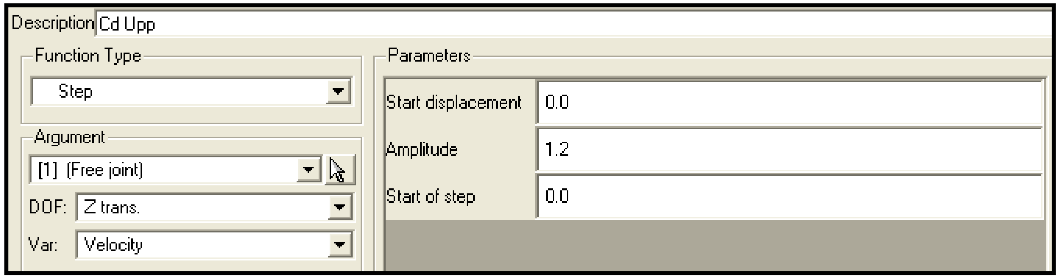
Use the following drop down menus from the toolbar and create the diagram as shown in the next slide (Give the appropriate descriptions to each section)

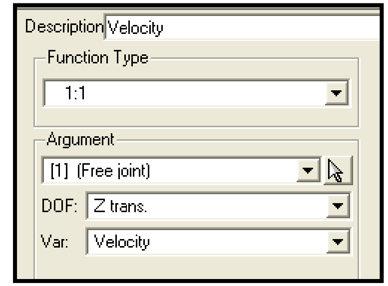
Diagram

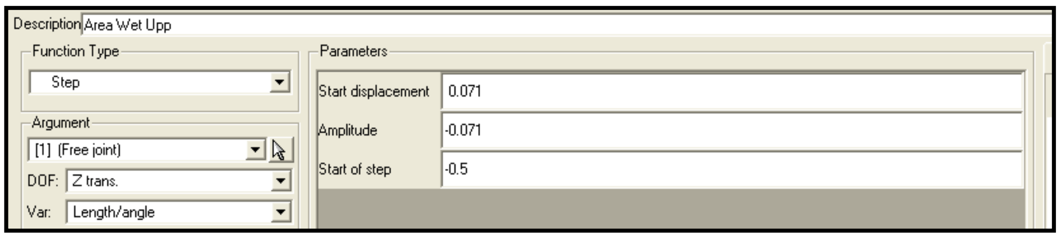

Velocity
V^2
1/2 x P
VDC
Velocity
Drag
S(v)
Cd Upp
Cd Area Upp
Area Wet Upp
Buoyancy
Sum Buoyancy Drag
VD
Area Wet Side
Cl Skin Friction coef
Cd Down
Cl Area Down
Area Wt Down

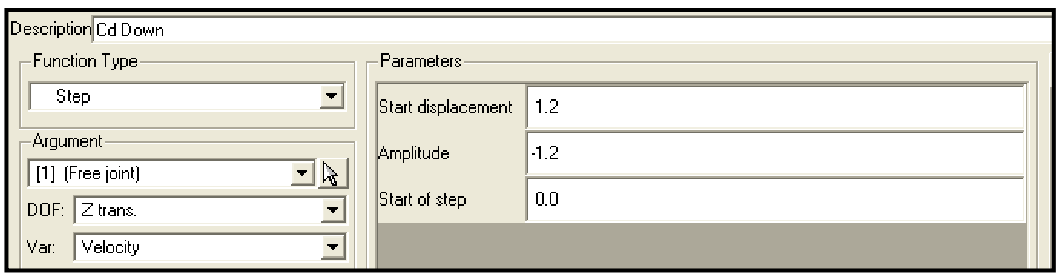
Component Features

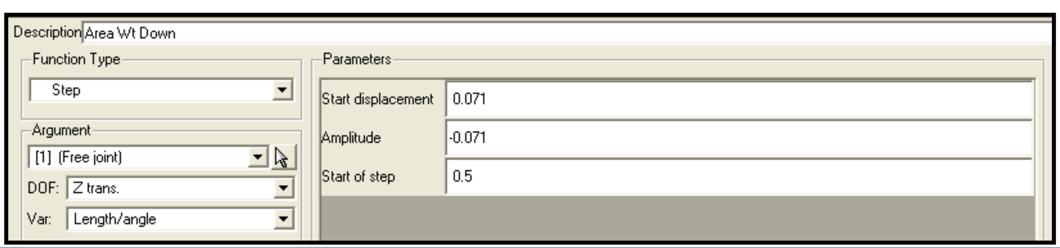
All the components created in the diagram has a function that needs to be defined. Shown below are the property manager inputs.



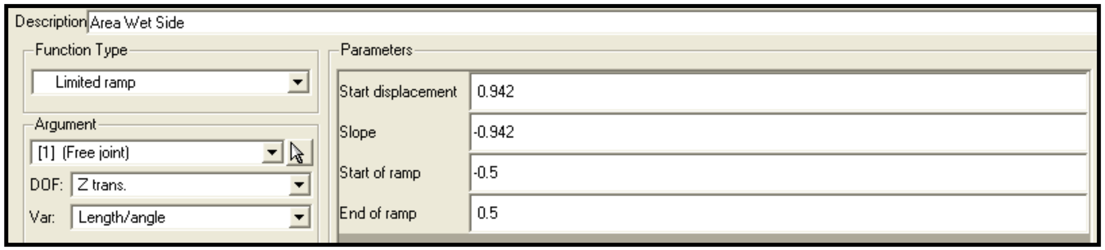


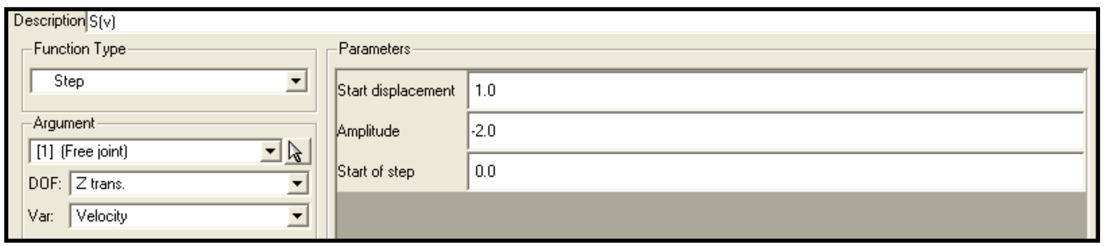


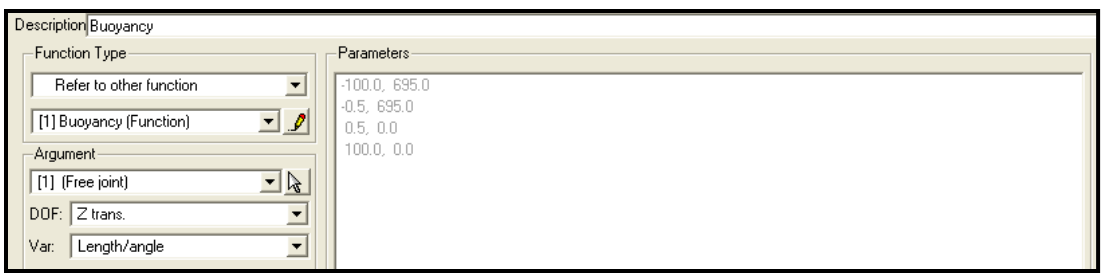


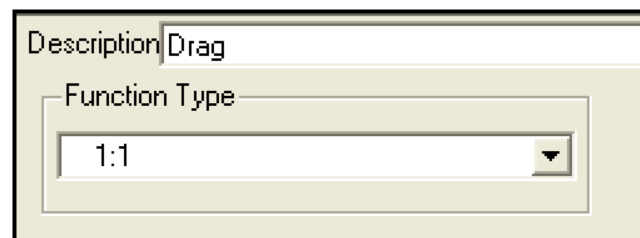


Component Features









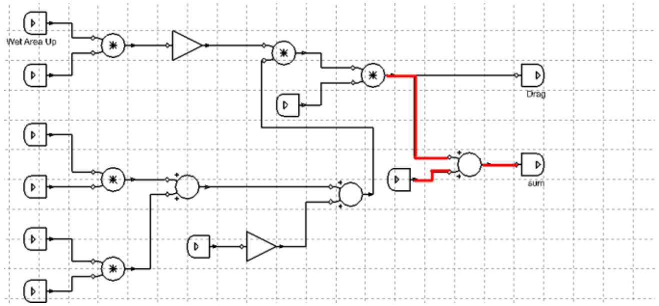
Control Output

FEDEM

1. Add another force to the cylinder by following the same procedure as previously presented (same direction as buoyancy)
2. Name the force ”Drag” and use Drag[CtrlOut] as magnitude in the Property Manager (output from control system)
3. Run simulation

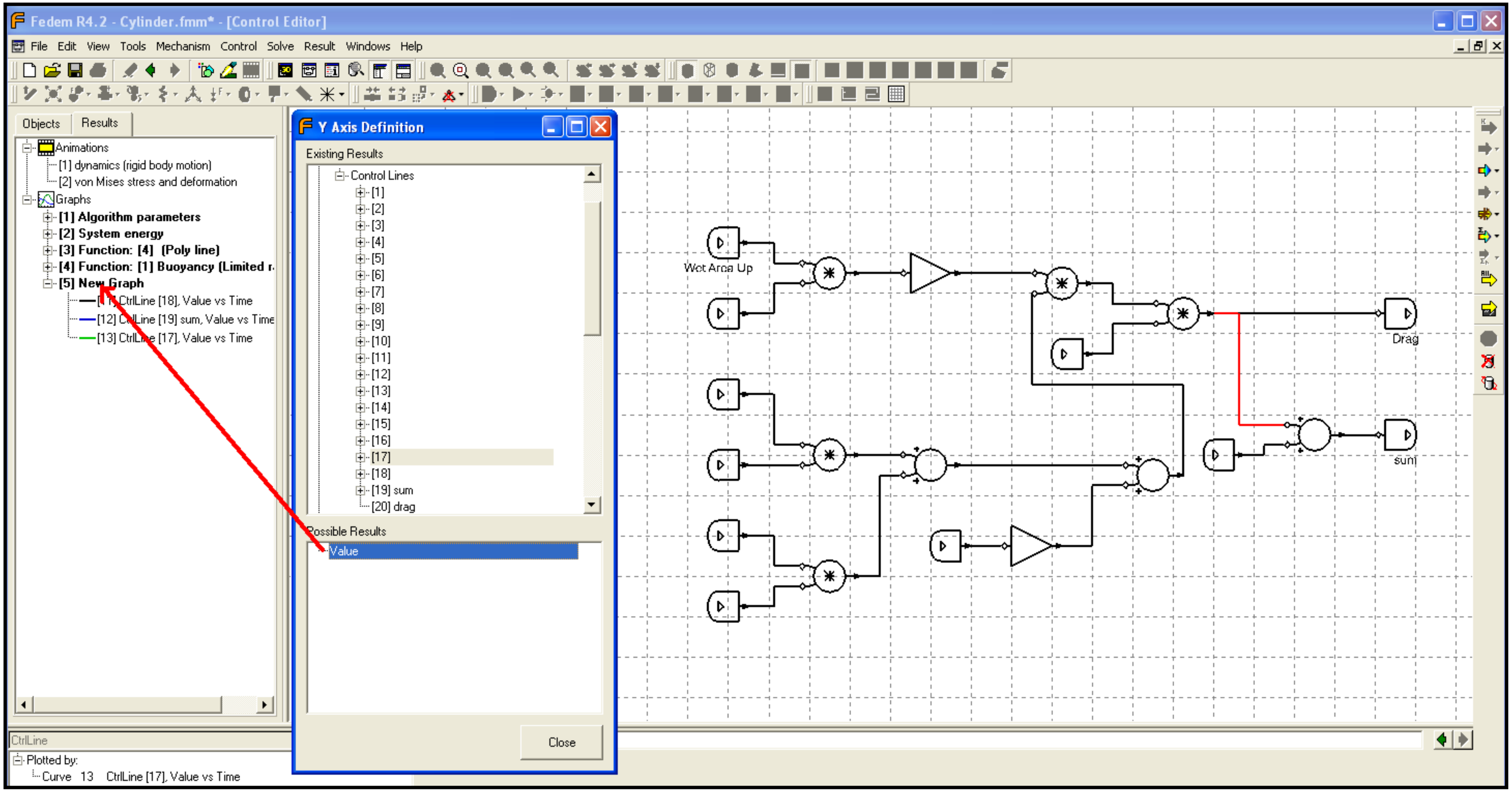
The drag force is now added to the system. To view the results graphically, enter the result tab and expand the Graph tree.

1. Right click, select new graph.
2. Right click, select ‘’result selector’’
3. Identify the name (number) of the following lines (marked with red)



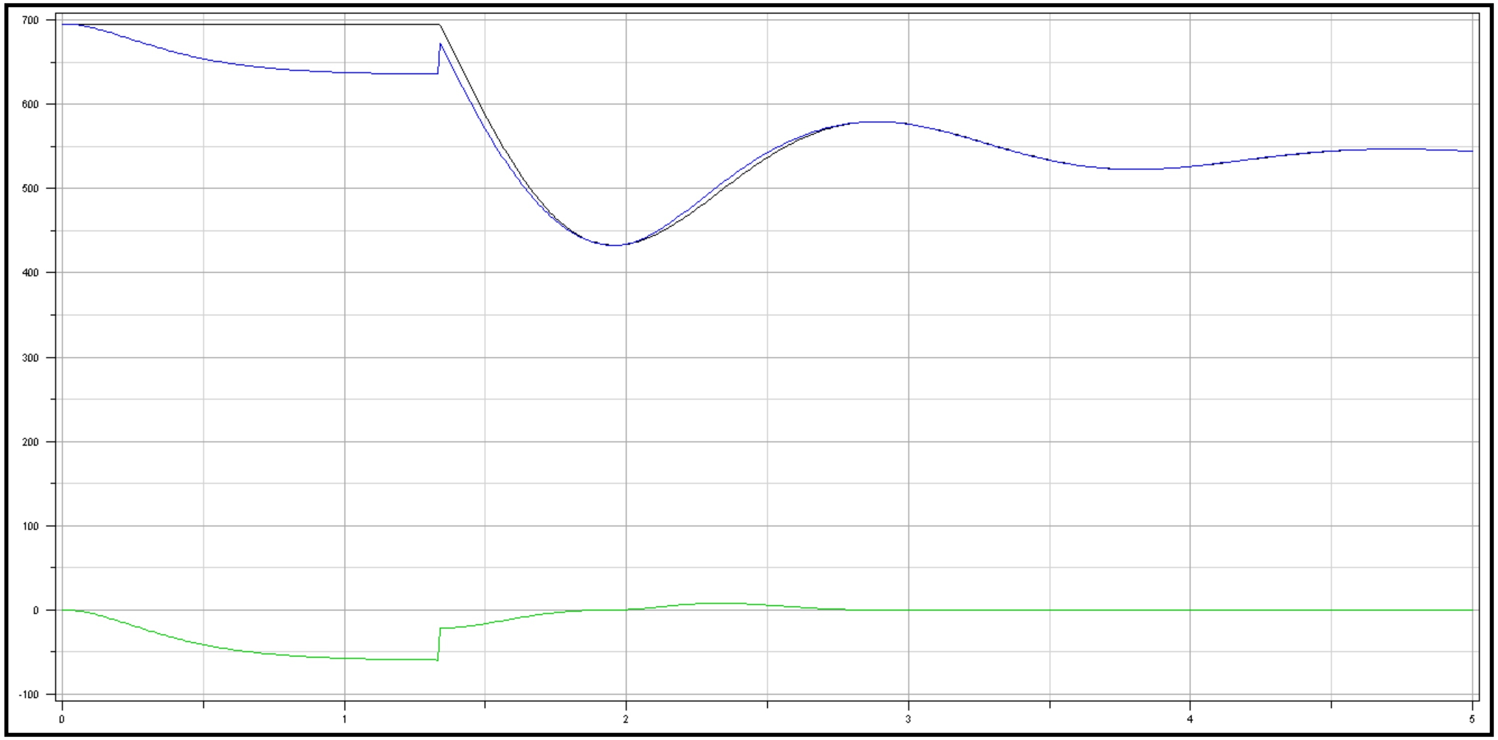
Control Output Cont.

When the lines are identified in the result selector, drag the value over to the New graph folder created previously.



Control Output Cont.

The graphs can then be viewed (by right clicking on the selected graph – Show Graph) after the dynamics have been solved. The graph should appear as shown below.

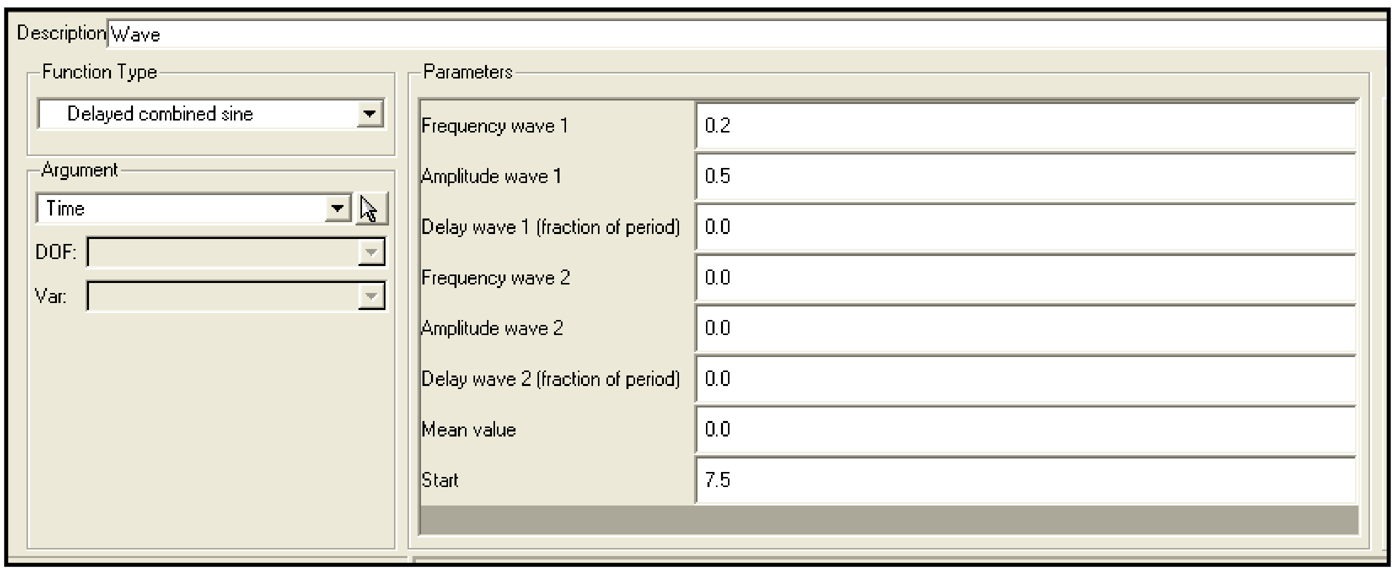


Note that the sum of the forces (here shown as blue) reaches equilibrium at approx 540 N which is the mass*g for the cylinder. Also note that the sharp decrease in drag is where the cylinder volume breaks the surface of the flatwave. Theses are good indication that the model is working as expected.

Adding Wave Motion

In order to simulate how the cylinder is acting when the flatwave is oscillating, a function has to be created with the purpose of describing the desired motion of the wave.

1. Delete previous solutions 
2. Right click in the Model Manager, Create Function
3. Name the function Wave and add the characteristics shown below



Applying Wave Motion

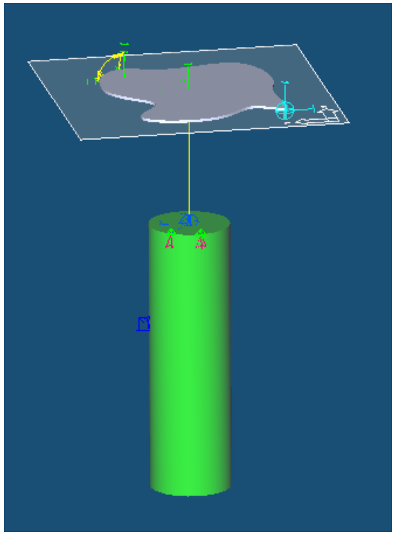
FEDEM

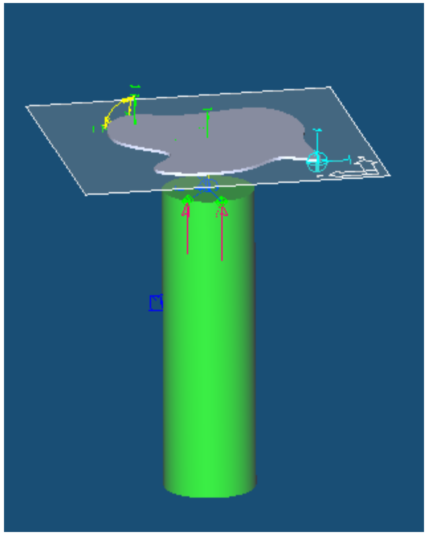
1. Select the joint connecting the flatwave (plate) to the workplane.
2. Change Tz to Spring-Damped in the Property Manager
3. Set the free length control option to initial deflection
4. Select the ‘’Wave’’ function (previously created) as the stress free length change.
5. Set the spring property to 1e10 (Enter)

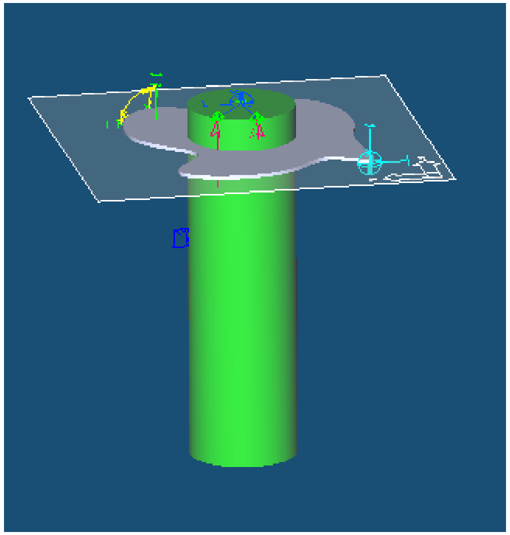
6. Now select the flatwave and change the position to X=-0.3, Y=-0.3, Z=0 (for visual purposes)
7. Change the stop time for the simulation to 25 sec (from 5 sec as previously defined)

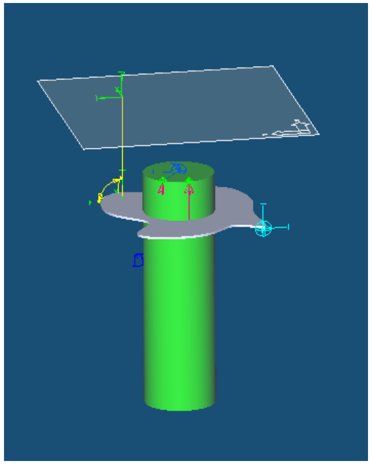
Solve the dynamics

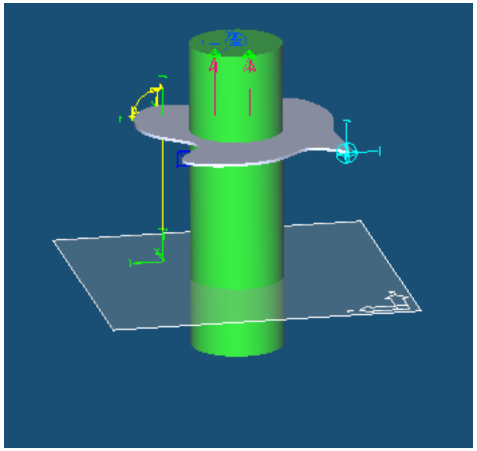
Now, the animation should show that the plate is moving up and down in an oscillation manner starting at 7.5 sec as defined in the Wave function.



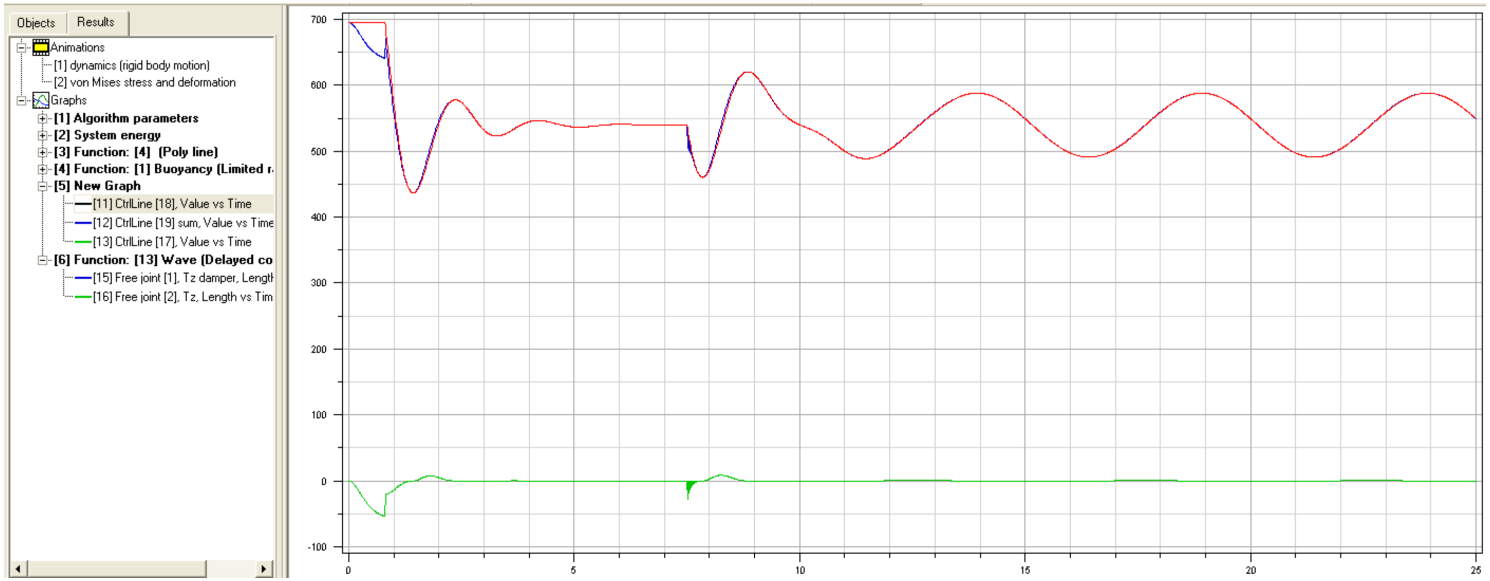




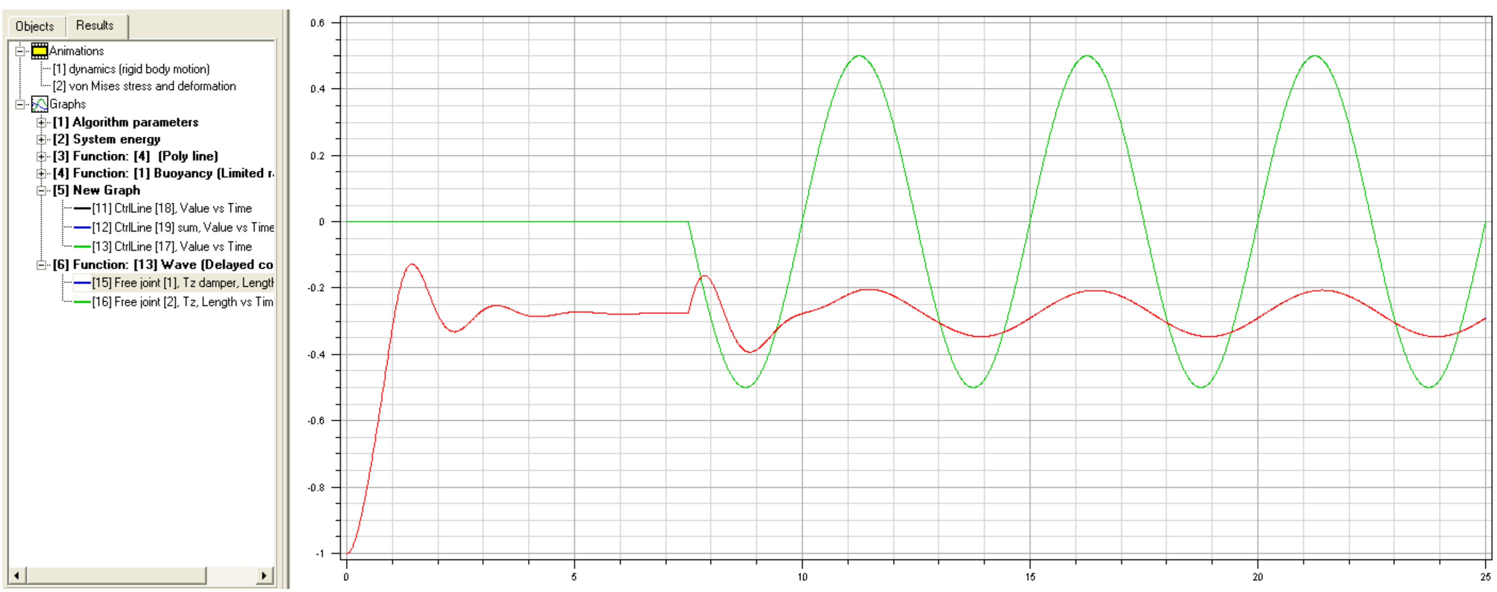




Results



Objects
Results
Animations
[1] dynamics (rigid body motion)
[2] von Mises stress and deformation
Graphs
[1] Algorithm parameters
[2] System energy
[3] Function: [4] (Poly line)
[4] Function: [1] Buoyancy (Limited r
[5] New Graph
[11] CtrlLine [18], Value vs Time
[12] CtrlLine [19] sum, Value vs Time
[13] CtrlLine [17], Value vs Time
[6] Function: [13] Wave (Delayed co
[15] Free joint [1], Tz damper, Lengtl
[16] Free joint [2], Tz, Length vs Tim
700
600
500
400
300
200
100
0
-100
0
5
10
15
20
25



Objects
Results
Animations
[1] dynamics (rigid body motion)
[2] von Mises stress and deformation
Graphs
[1] Algorithm parameters
[2] System energy
[3] Function: [4] (Poly line)
[4] Function: [1] Buoyancy (Limited r
[5] New Graph
[11] CtrlLine [18], Value vs Time
[12] CtrlLine [19] sum, Value vs Time
[13] CtrlLine [17], Value vs Time
[6] Function: [13] Wave (Delayed co
[15] Free joint [1], Tz damper, Lengtl
[16] Free joint [2], Tz, Length vs Tim
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
5
10
15
20
25

Additional

In addition to the presented results it is now possible to test the model for several cases.

Some Examples:

- Deeper release depth
- Higher amplitude wave
- Higher frequency wave
- Different mass property of cylinder

Also look at some of the physical principles used with respect to the motion of the cylinder and plot curves that validate the assumptions made in the earlier stages of the model setup

This tutorial has presented how dynamic motion can be simulated and analyzed by the use of the integrate control system FEDEM has. This tutorial has only presented the most basic example as means of illustrating the remarkable possibilities FEDEM offers with respect to FEM dynamic solving

End