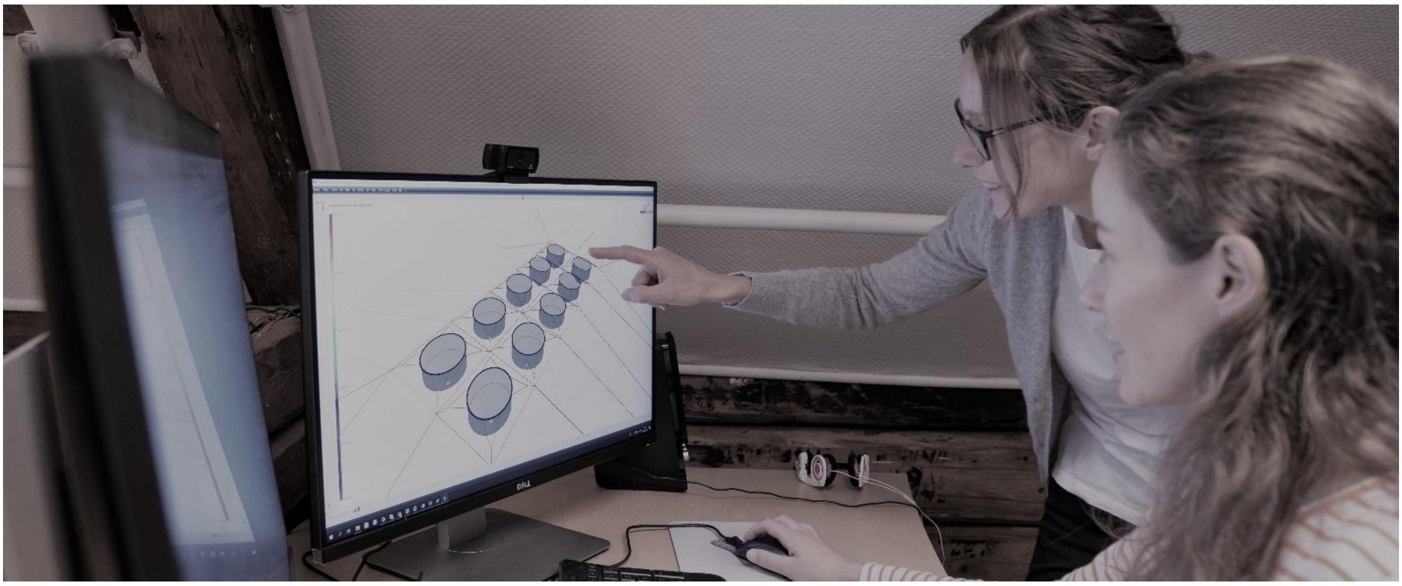
AquaSim training courses

- **Tarpaulin closed compartment**



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Content

1 Prerequisites

The tutorial presents a simple case study with the purpose of demonstrating functionality in AquaSim.

It is assumed that the user is familiar with the basic principles of modelling and specifying material parameters in AquaEdit, as well as conducting analyses. If you are looking for an introduction to AquaSim we advise you to start with the Basic program tutorials.

2 Learning objectives

In this tutorial, you will be introduced to how establish and analyse static equilibrium of a hemispherical shaped tarpaulin attached to a floater. This includes the following steps:

- Modelling of a hemispherical tarpaulin closed compartment.
- Analysis of equilibrium in seawater.
- Analysis of equilibrium in brackish water.
- Analysis of equilibrium with fresh water.

3 Introduction

Checking static equilibrium is important to ensure the model is stable and correctly set up. More specifically:

- Balance internal- and external forces: in water, structures are subject to buoyancy, gravity, hydrostatic pressure, tension from mooring etc. These forces must be balanced out to so that the model does not accelerate or rotate.
- Correct boundary conditions: if equilibrium is not satisfied, it often means that there is something wrong with the boundary conditions. This may be ill defined mass distribution, lack of buoyancy, wrong fluid density and so on.
- Numerical stability: having balanced the internal- and external forces and correct boundary conditions, this facilitates numerical stability in further analyses.

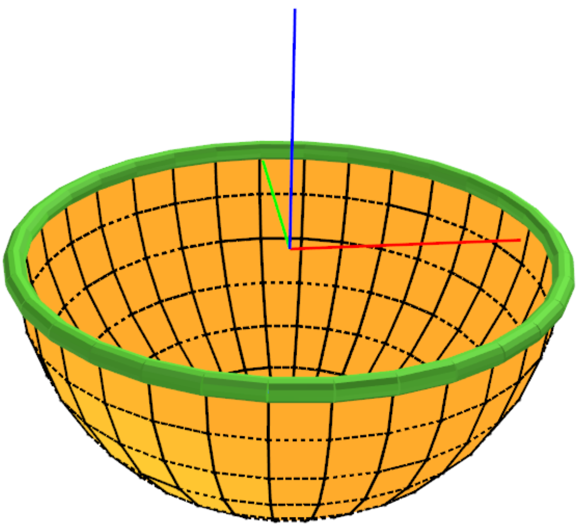


Figure 1 Hemispherical tarpaulin and floater, in AquaEdit

When assessing static equilibrium for closed compartments, some key parameters are considered. In this tutorial it involves:

- Control of waterline level for the fluid inside the compartment. This is often referred to as "internal waterline".
- Control of relative pressure between fluid inside- and outside the compartment.
- Control of how fluid density affects the model's floating position.

4 Case study – Tarpaulin closed compartment

4.1 Create analysis model in AquaEdit

The model is created in two main steps: first the tarpaulin, then the floater. The hemispherical tarpaulin can be modelled in several ways, here are two suggestions:

1. Use the "Draw tube" tool and make a conical bottom. Then use the "Scale" functionality to make the cone a hemisphere.
2. Use the "Draw circle" tool, half it and then use the "Extrude" functionality with rotation, to generate the hemisphere.

The latter is chosen to be demonstrated in this tutorial.

4.1.2 Create tarpaulin closed compartment

First establish a component type Membrane, then click the "Draw circle", as illustrated in Figure 2.

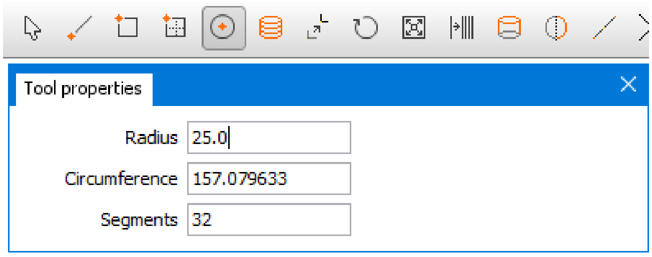


Figure 2 Draw circle

The circle is centred in origin, and rotated to the xz-plane. Then delete the upper half of the circle as shown in Figure 3.

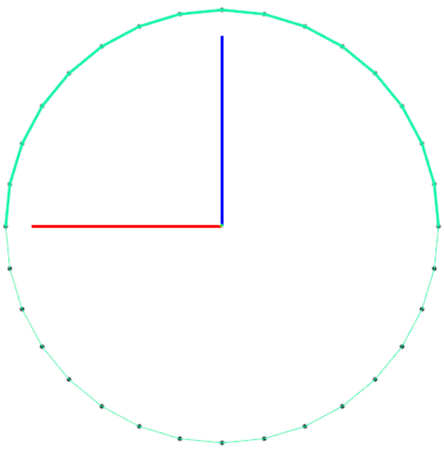


Figure 3 Delete the upper half of the circle, as marked

The remaining half of the circle is shown in the figure below.

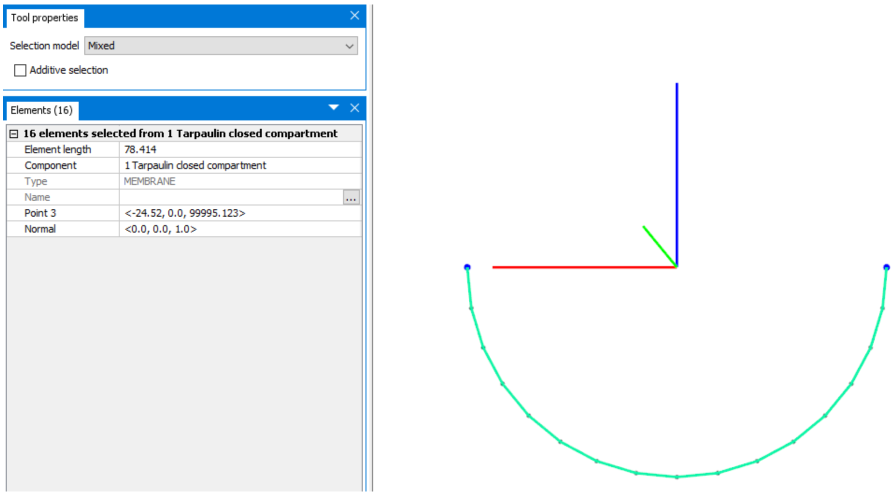


Figure 4 A half circle with 32 elements in xz-plane

Select all the elements and click “Extrude”. Apply 16 segments and rotate 180 degrees about z-axis.

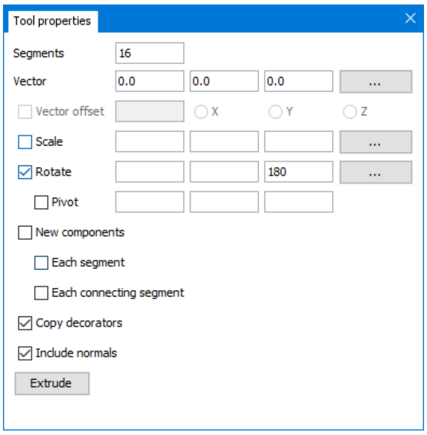


Figure 5

A hemisphere, as shown in Figure 6 is established.

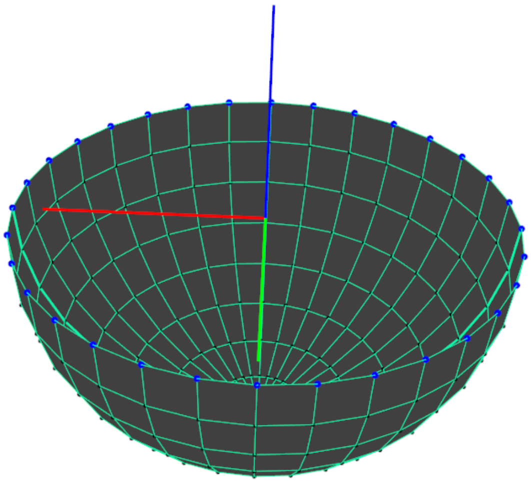


Figure 6

In order for triangular elements to be introduced to the membrane, the membrane needs to be of type MembraneX. Hence, the lines in the bottom part of the hemisphere are selected and moved to another component. This is illustrated in the figure below.

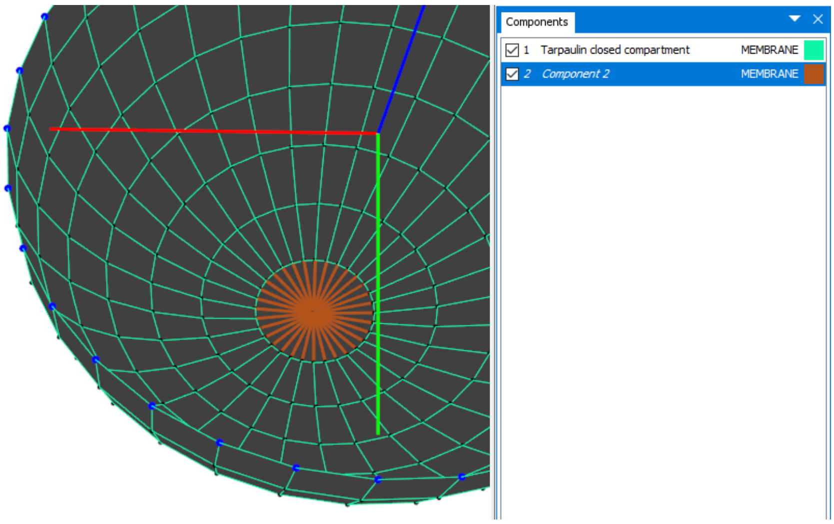


Figure 7 Bottom part of hemisphere is moved to another component

Then change the component type for "Tarpaulin closed compartment" from type Membrane to MembraneX. This is done by right-clicking the component select Type > MembraneX.

Triangular elements are added by utilizing "Draw membrane" and select "Triangular mode" in the Tool properties-section, see Figure 8. Remember to have the component "Tarpaulin closed compartment" selected.

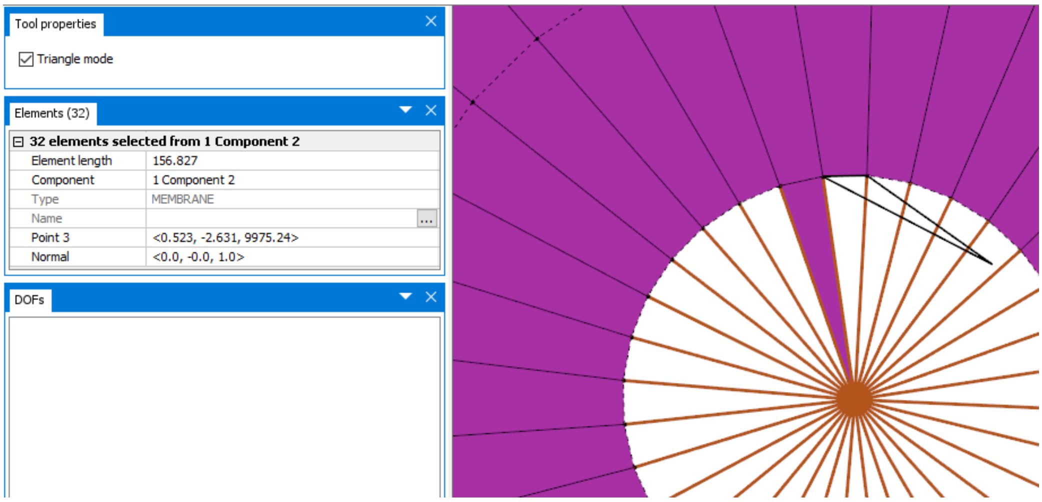


Figure 8 The "Draw membrane" option with "Triangle mode" activated.

Draw the triangles to fill the bottom. When this is done you can delete the other component group. Now we have a complete hemisphere consisting of MembraneX, Figure 9.

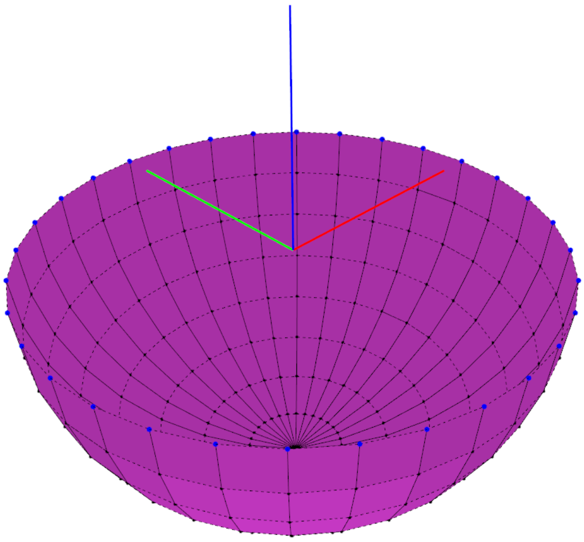


Figure 9 Hemisphere in component type MembraneX

It is important for AquaSim to know which way the membrane panels are oriented. This can be checked through selecting the option Normals and then select alle the membrane panels, as seen below.

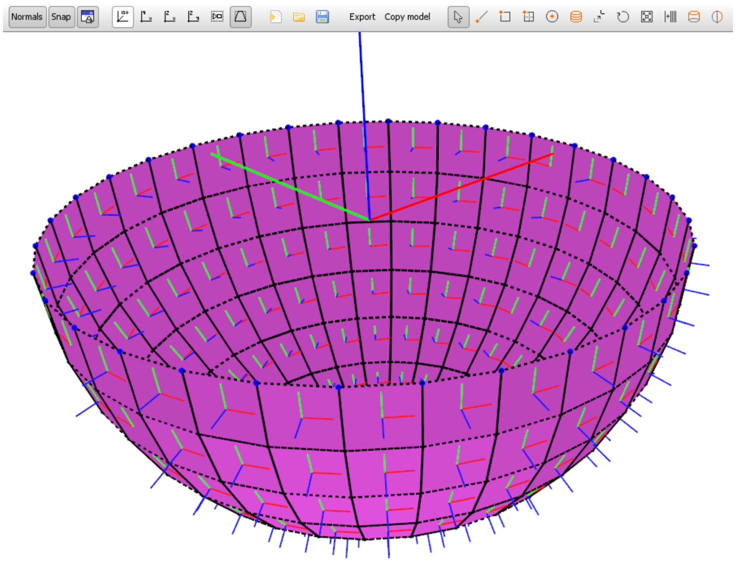


Figure 10 Membrane panel normal, normal direction is the blue line

These should be centered towards geometric center. When all the panels are selected, right-click > Membrane > Align membranes to panel center. This is illustrated in Figure 11.

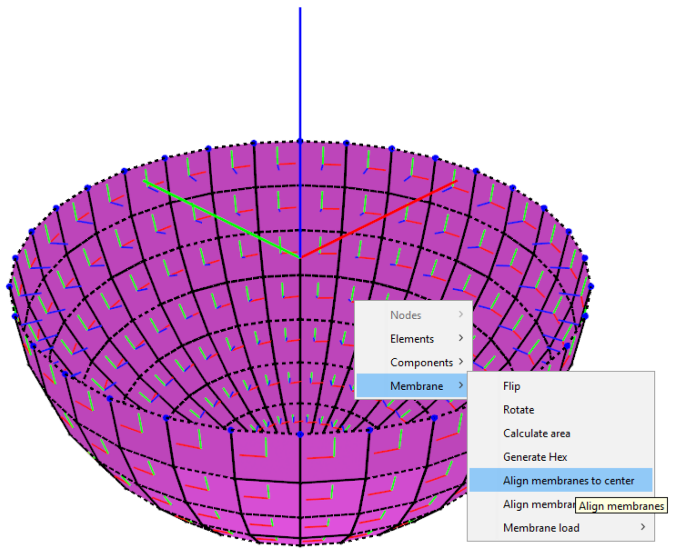


Figure 11 Normals centered to the geometric center

One may validate the directions by activating the "Membrane side" button as shown in Figure 12

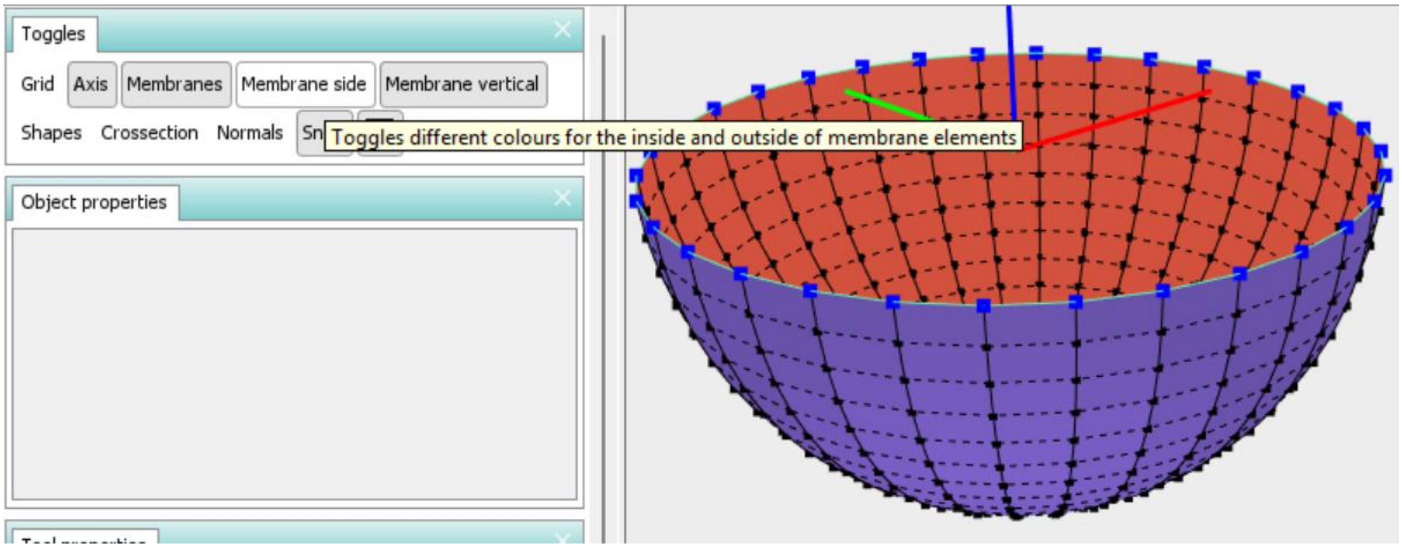
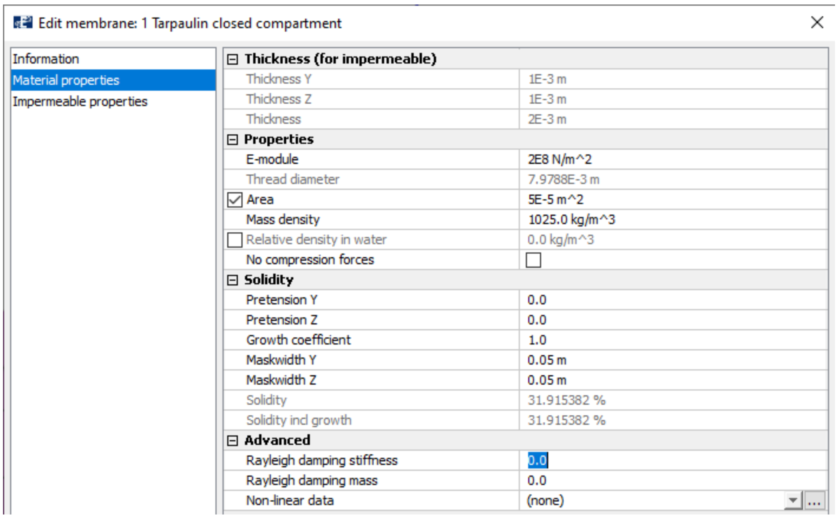


Figure 12 Membrane side activated

Double-click the component type to enter the Edit MembraneX-window. Select Type: Normal and Load formulation: Closed compartment.

Figure 13 shows the material properties for this case study. Note that a mask width of 5 cm is chosen. This corresponds to standard width of test-specimens when determining material data for tarpaulins. If the tarpaulin has different properties in warp and weft directions, one must have a different mask width in the other direction.



Edit membrane: 1 Tarpaulin closed compartment

Information
Material properties
Impermeable properties

Thickness (for impermeable)	
Thickness Y	1E-3 m
Thickness Z	1E-3 m
Thickness	2E-3 m
Properties	
E-module	2E8 N/m^2
Thread diameter	7.9788E-3 m
Area	5E-5 m^2
Mass density	1025.0 kg/m^3
Relative density in water	0.0 kg/m^3
No compression forces	
Solidity	
Pretension Y	0.0
Pretension Z	0.0
Growth coefficient	1.0
Maskwidth Y	0.05 m
Maskwidth Z	0.05 m
Solidity	31.915382 %
Solidity incl growth	31.915382 %
Advanced	
Rayleigh damping stiffness	0.0
Rayleigh damping mass	0.0
Non-linear data	(none)

Figure 13 Material properties of the tarpaulin closed compartment

Then parameters for in Impermeable properties has to be defined, this is shown in Figure 14

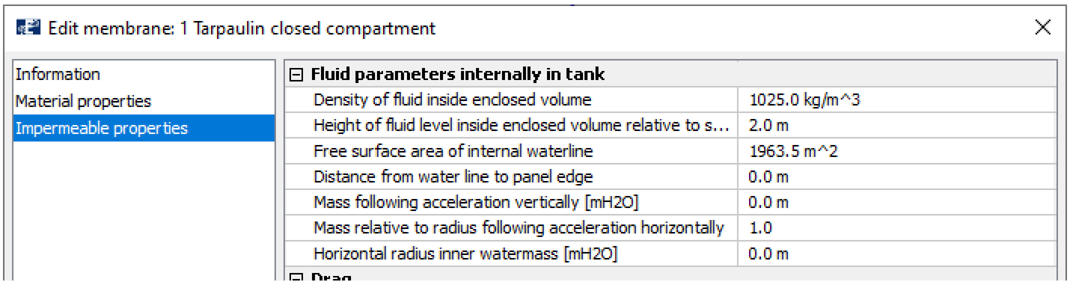


Figure 14 Parameters for defining fluid inside the closed compartment

- **Density of fluid inside enclosed volume:** this is the density of the internal fluid. Normally 1025kg/m3 for seawater and 1000kg/m3 for fresh water.
- **Height of fluid level inside enclosed volume relative to sea level:** this is the height of the water (positive upwards) of water inside the enclosed volume. This is the waterline in the drawn not-deformed structure. This determines the volume of the inside fluid. This volume is assumed constant during the analysis, such that if the structure deforms downwards in the way that the volume below the waterline becomes larger, the height of fluid will decrease and vice versa.
- **Free surface area of internal waterline:** this is the area of the water surface inside the enclosed volume. This is assumed constant in the analysis. And if the volume below the waterline increases, the fluid height will decrease.
- **Distance from water line to panel edge:** this parameter is set in case one would like to include that the water pours out if it exceeds this value (this is relative to the lowest point of the upper line on the enclosed volume). Note that there is no mechanism working the other way around, such that the total water volume can only decrease as analysis progresses.

4.1.3 Create floater

A simplified floater is created by establishing a beam component and drawing a circle along the top of the tarpaulin closed compartment. Use the AquaSim built in Wizard to create a tube, see Figure 15

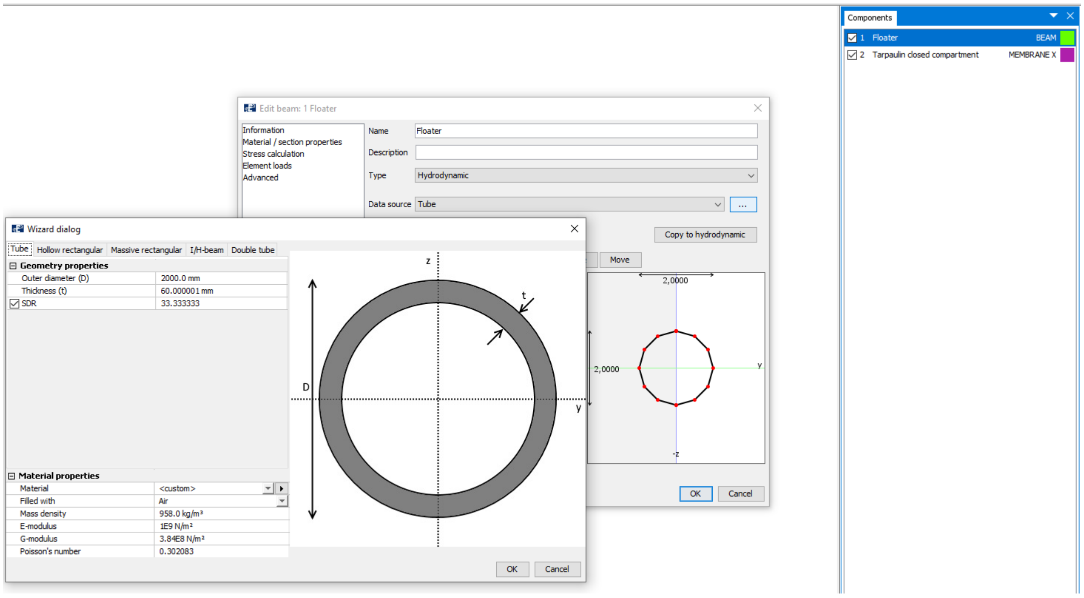


Figure 15 Properties of Floater

Since the model is a simplified structure not including mooring, the nodes along the floater are restrained from horizontal motions, see Figure 16.

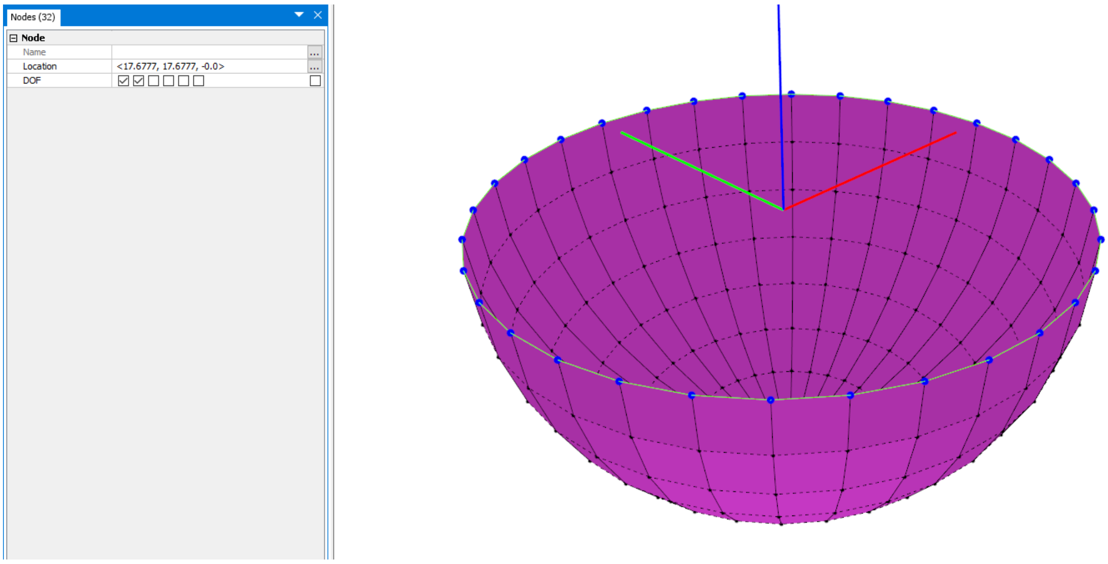


Figure 16 Nodes in top are restrained in x- and y-direction

Now we have a complete model in Figure 17.

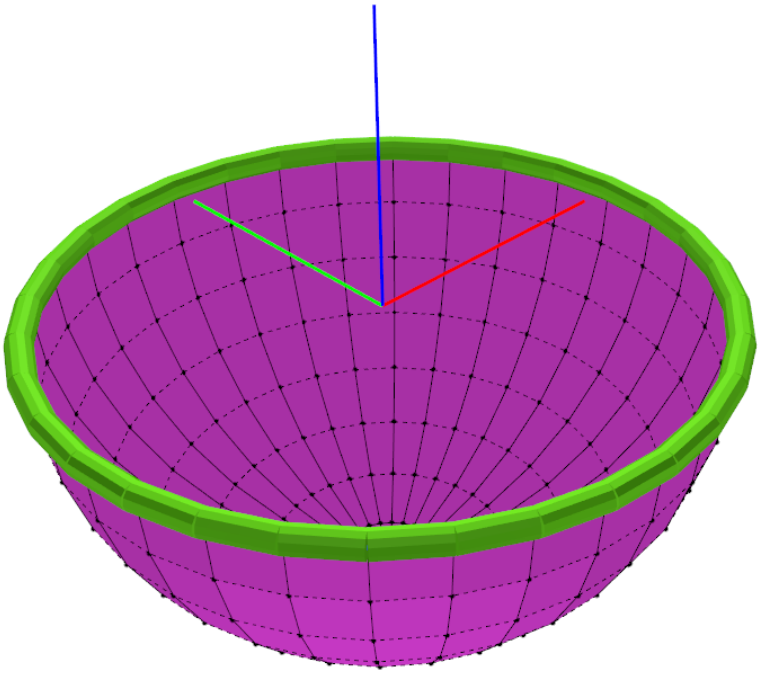


Figure 17 Complete model of tarpaulin closed compartment and floater

Since we do not want AquaSim to change the orientation of the membrane normal, remember to check on the “Membrane normals are verified” in the Export-menu. A static analysis (without current) is run.

4.2 Find static equilibrium and validate model AquaView

The system is analyzed with fluid density of 1025 both inside the tarpaulin closed compartment and outside. How the inner water surface height has raised or decreased is found in Result > Impermeable net > Inner height waterline [m].

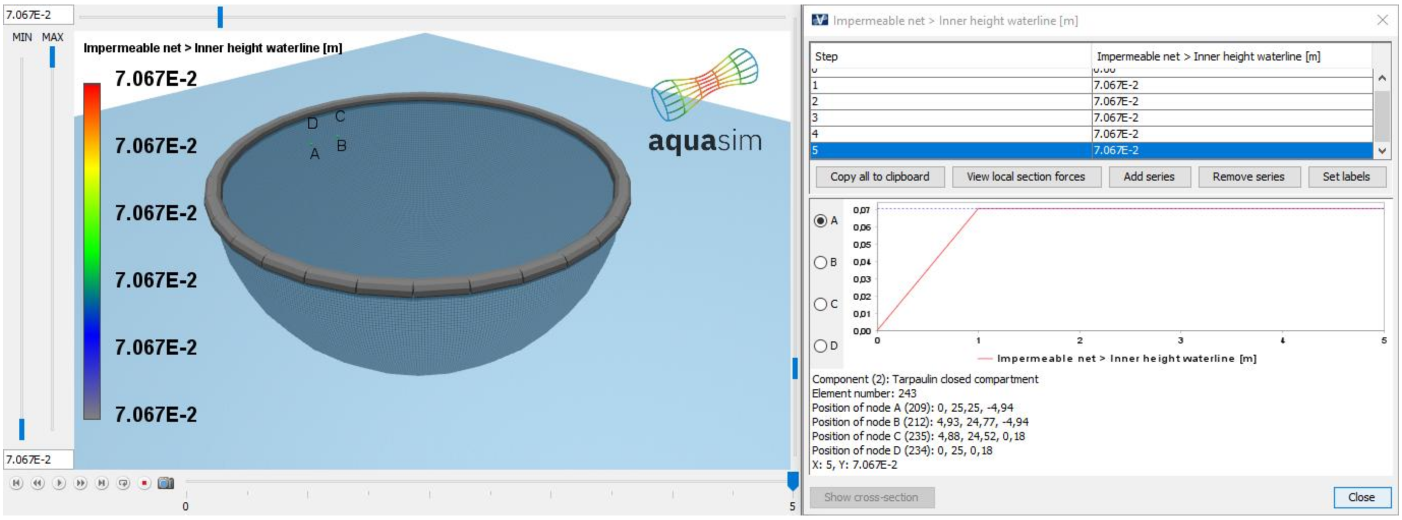


Figure 18 Inner height of waterline in AquaView

The inner water surface height at static equilibrium is in this case about 7 cm above the outer mean waterline. Having defined a height of 2 meters, this means that the water volume between 2 meters and 7 cm has moved downwards during the analysis.

There are two ways the water can move downwards; the first is that the floater moves downwards with reduced freeboard. The other is that the tarpaulin moves downwards and outwards from stretching. To determine this, one can plot the vertical displacement, Result > Displacement > Displacement Z.

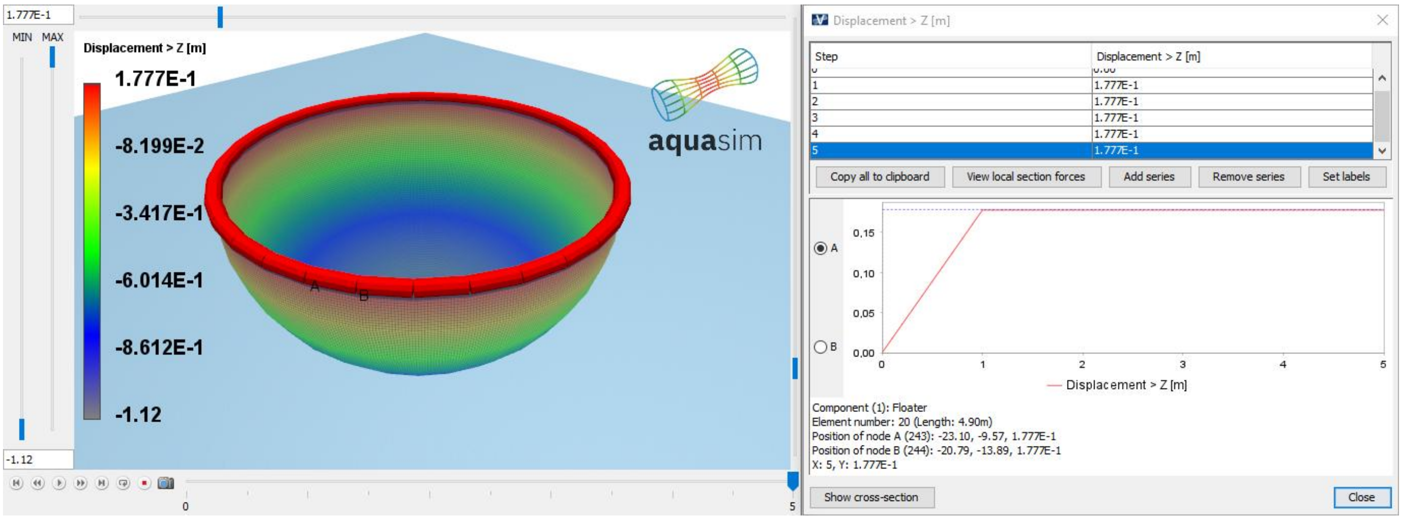


Figure 19 Vertical displacement of floater

From Figure 19 it is noted that the floater rises by approximately 18 cm, hence the tarpaulin moves downwards from stretching. The bottom part moves approximately 1 meter downwards as shown in Figure 20.

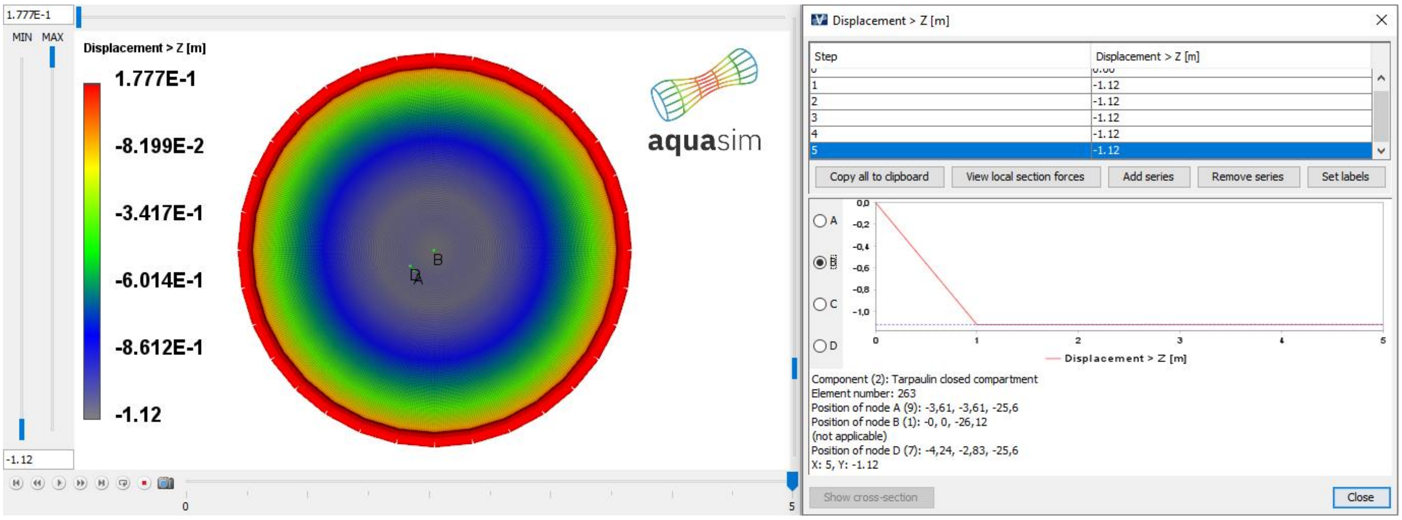


Figure 20 Vertical displacement of tarpaulin

In addition, there is motion horizontally of the tarpaulin. This is about 1 meter, see Figure 21.

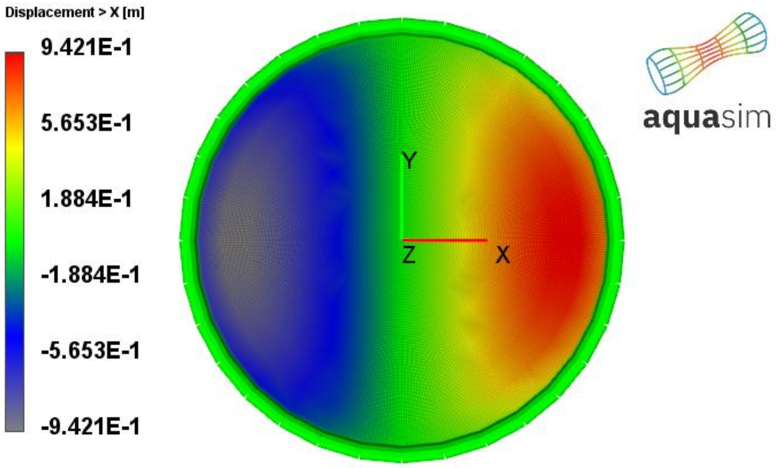


Figure 21 Displacement in x-direction

4.3 Brackish water

Now we introduce brackish water on the outside of the tarpaulin closed compartment. This parameter is found in Export > Non linear density field, see Figure 22. Fluid density for brackish water is assumed 1010 kg/m3.

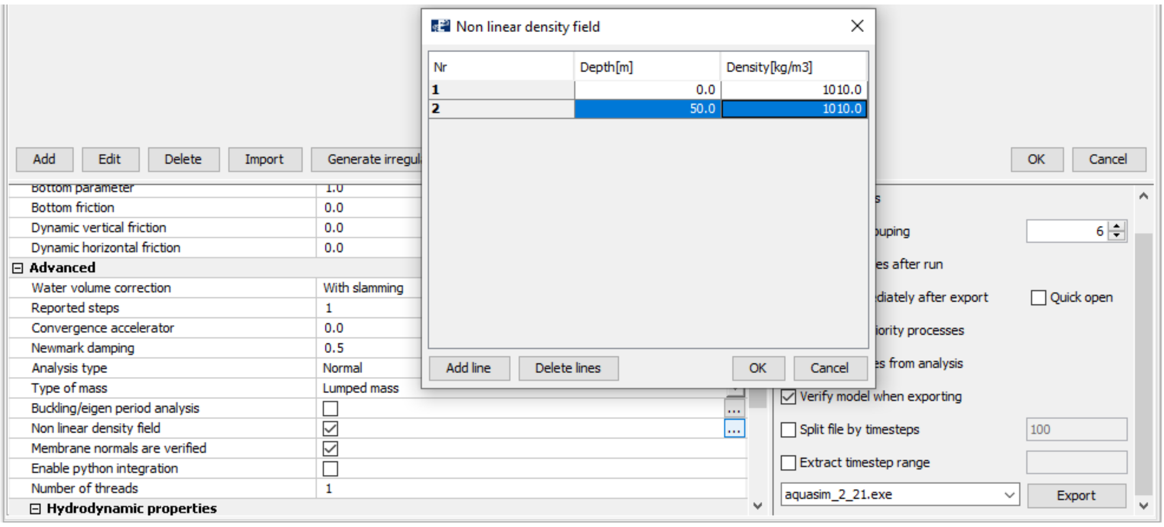


Figure 22 Brackish water for fluid outside the tarpaulin

A fluid density of 1025kg/m3 is kept on the inside of the tarpaulin. Having analyzed static equilibrium, we see that the floater moves approximately 8 cm downwards. This is seen in Figure 23, where one also can see the bottom of the tarpaulin displaced downwards.

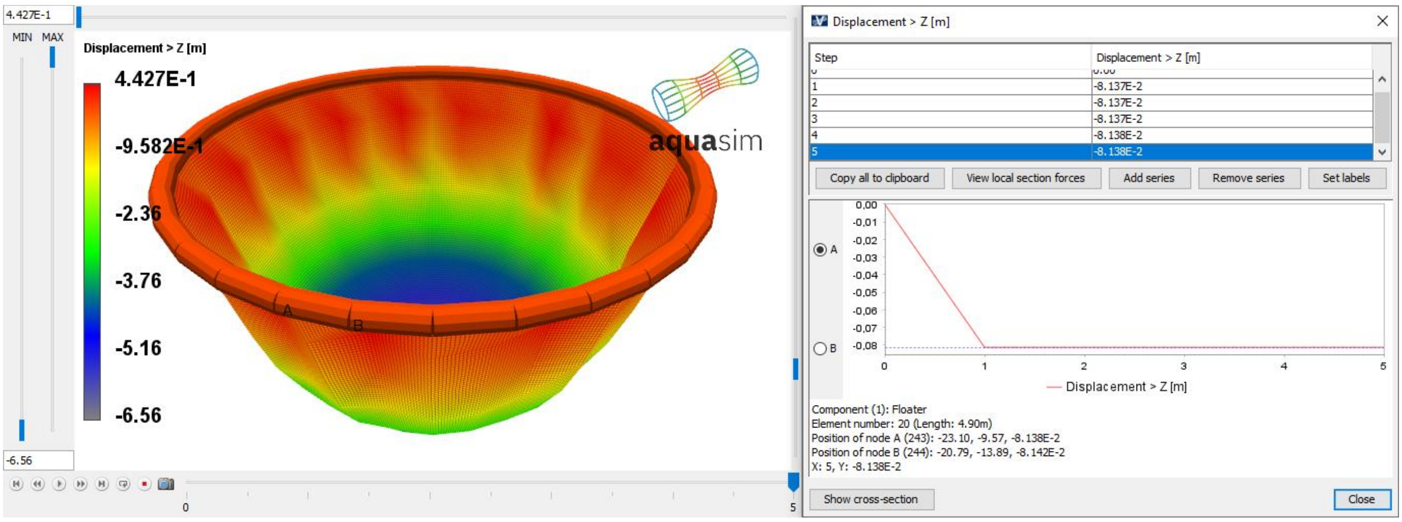


Figure 23 Vertical displacement of floater

The bottom of the tarpaulin, Figure 24, displace about 6.5 meters downwards.

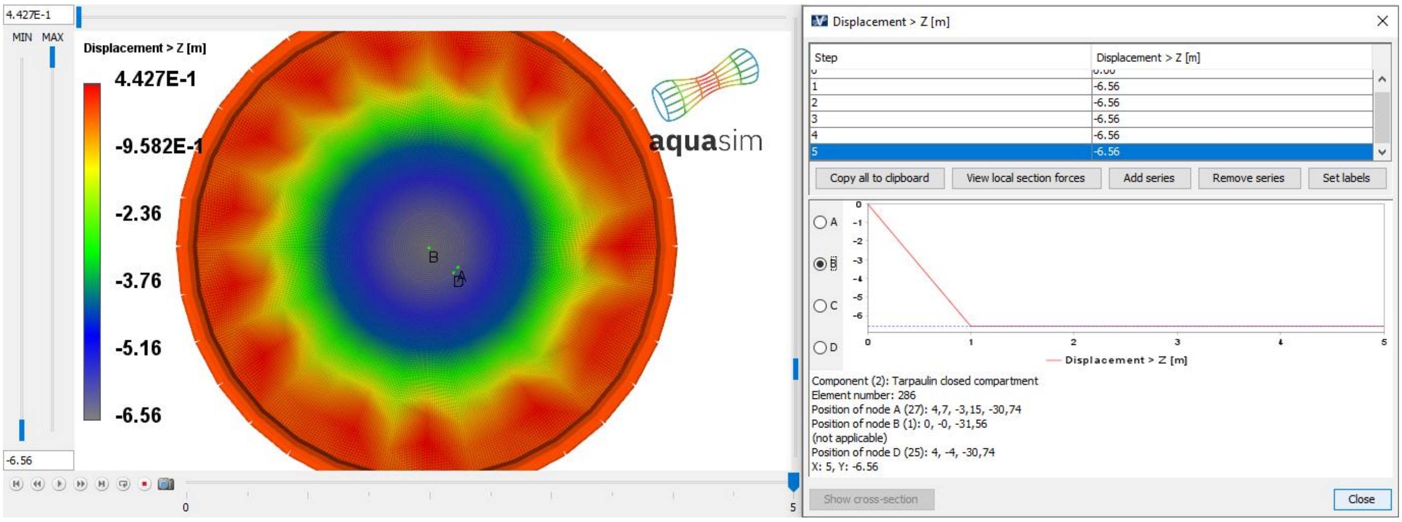


Figure 24 Vertical displacement of tarpaulin closed compartment

At equilibrium, the inner waterline is about 15.9 cm below the mean water surface, see Figure 25.

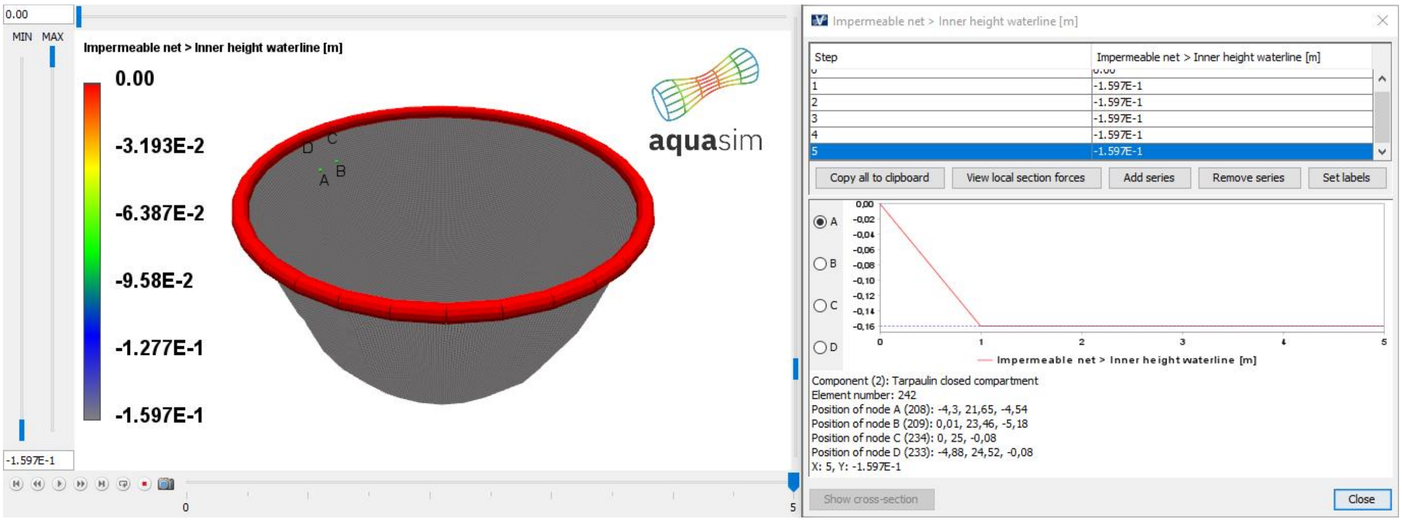


Figure 25 Location of inner waterline at equilibrium

This means that if you would like to have the inner waterline above the outer waterline, you will have to introduce more water to the system.

The relative pressure between the outside- and inside water is shown in Figure 26.

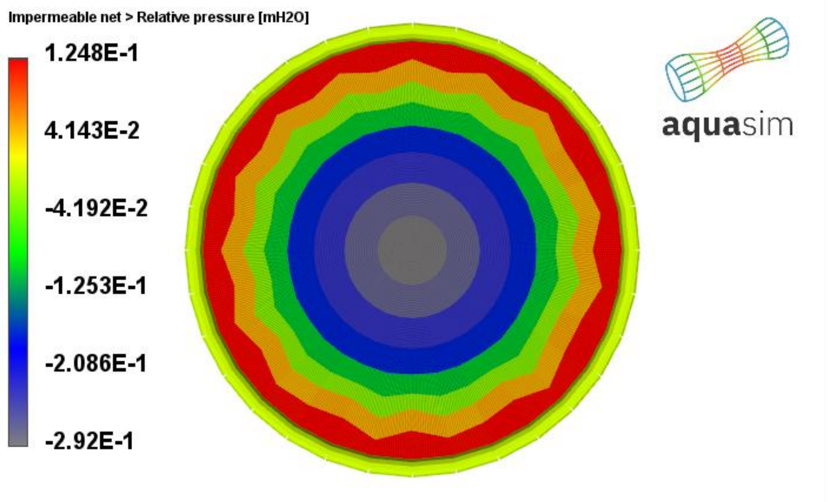


Figure 26 Relative pressure, positive value is inwards the enclosed volume

As seen from Figure 26there is a net pressure inward in the upper part of the tarpaulin, and net pressure outwards in the lower part.

As seen from the figures in this section, brackish water means more weight needs to be carried by the floater. Intuitively, there is a risk by having the inner waterline below the outer: rainfall or waves pouring more water into the tarpaulin closed compartment will increase the weight carried by the floater. Eventually one risks the structure to sink. One must be able to transport excess water out of the enclosed volume. Systems may have valves in the bottom area, in this case with brackish water it may be a good choice to have valves closed to the bottom in cases where the outer density is lower on the outside compared to inside the volume as there is higher pressure on the inside in this area as seen in Figure 26.

4.4 Fresh water

If one likes to use a tarpaulin to enclose fresh water, this has opposite effect of brackish water. To illustrate this, one case has been analyzed where the modeled inside water is that of a full hemisphere. See Figure 27.

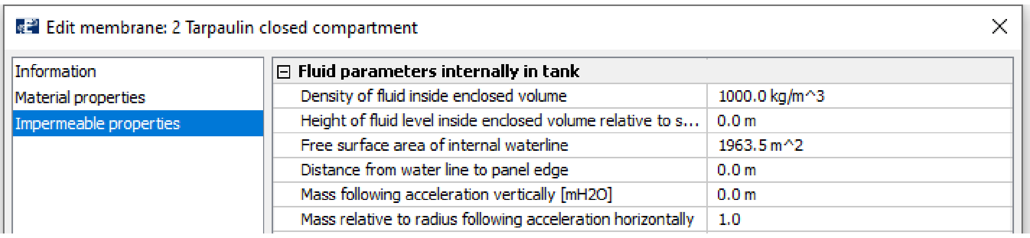


Figure 27 Input for case with fresh water

Vertical displacement of floater and tarpaulin is plotted in Figure 28. As seen here, the floater raises about 54 cm upwards and the tarpaulin bottom about 7.8 meters.

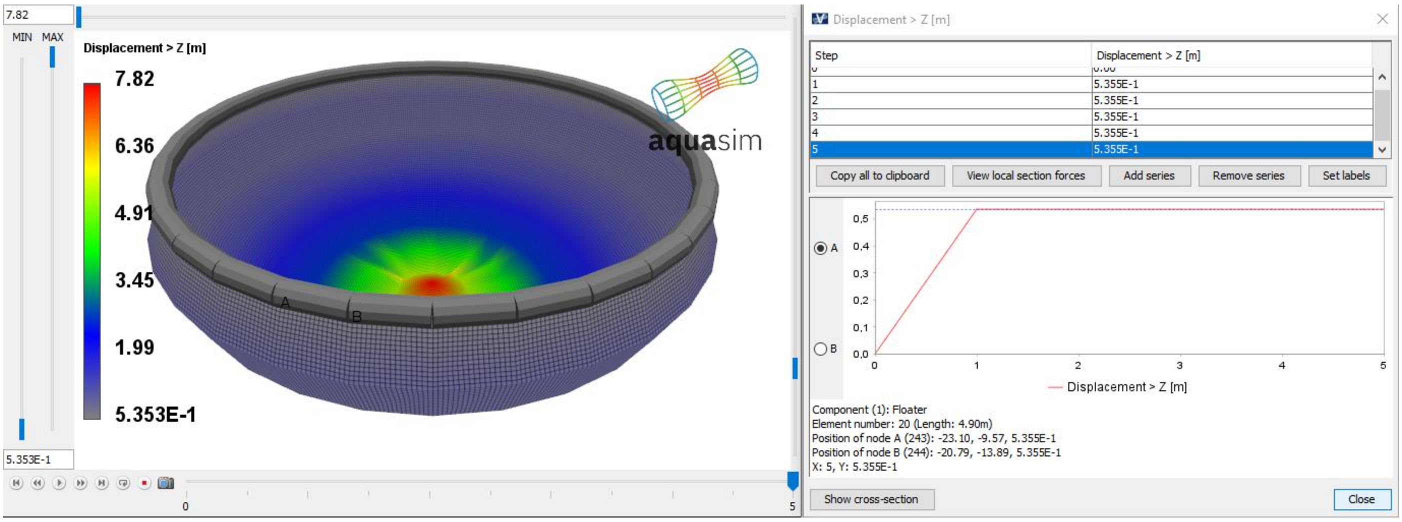


Figure 28 Vertical displacement of floater and tarpaulin closed compartment

Figure 29 shows the displacement in x-direction, as seen the tarpaulin closed compartment is pushed 2.7 meters sideways in the area below the floater.

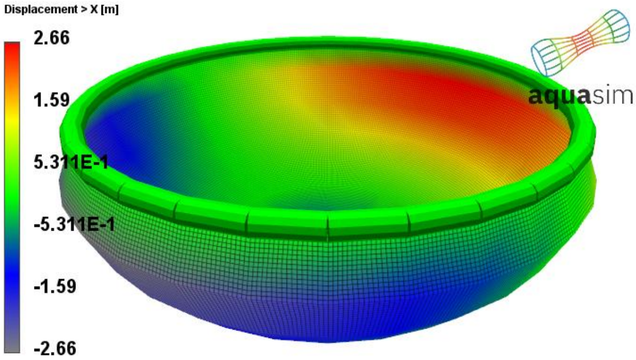


Figure 29 Displacement in x-direction

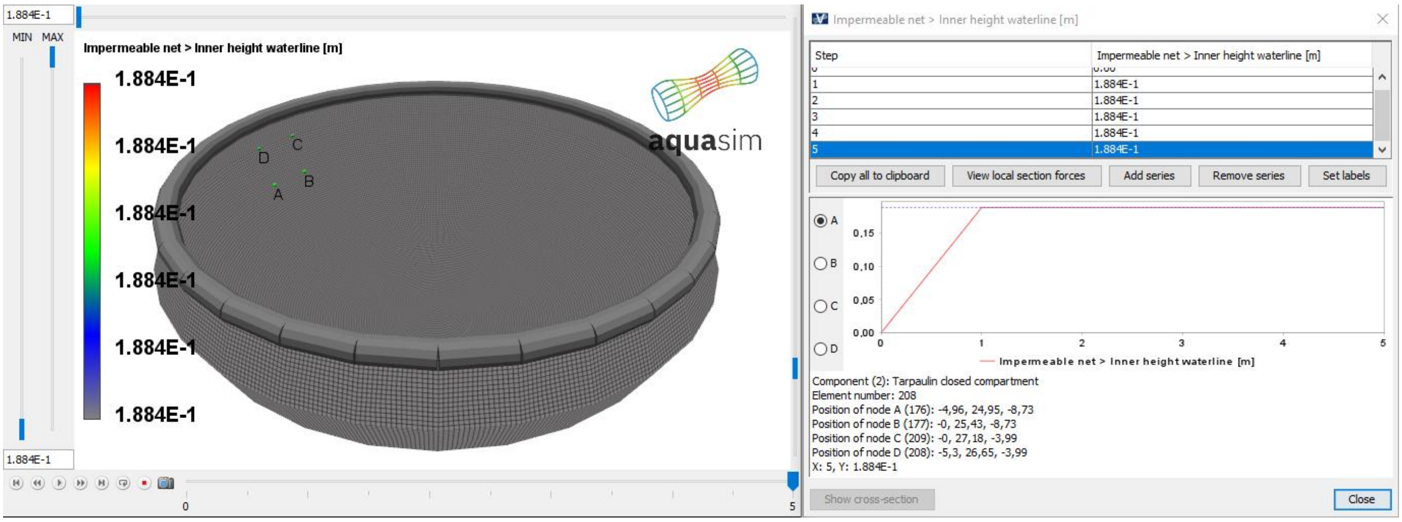


Figure 30 Inner height of waterline

Figure 30 shows, that for this case, the inner waterline is about 18 cm above the outer waterline. Figure 31 shows the relative pressure. As seen here, the relative pressure is slightly inwards along the bottom part of the tarpaulin. The pressure is largely outwards at the upper part. Which is logical with the respective densities and inner water height.

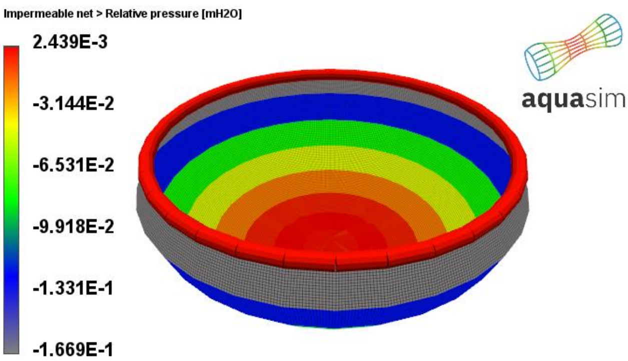


Figure 31 Relative pressure

5 Summary

Verifying static equilibrium ensure that the external forces are balanced correctly by the structure's internal forces. This is important prerequisites before further analyses with e.g. current, wind and waves and is important in itself.

- **Float position:** It should be investigated that float position is within acceptable ranges. There need to be sufficient buoyancy also in extreme cases with brackish water. Check that the system floats at the expected draft and don't sink. In this tutorial we investigated how the floater and tarpaulin displaced vertically and evaluated if this appeared logically given the different fluid densities. Also, how the tarpaulin expanded or shrunk was evaluated.
- **Relative pressure:** It is noted that pressure differences on the outside relative to the inside matters strongly for the position of the tarpauline. Having fresh water inside means one need the inside water line to be above the outside water line which gives a situation where there is internal overpressure in the tarpaulins upper part while there is external overpressure in the bottom area leading the tarpaulin to deform upwards in the botton and outwards in the upper area. checking the pressure balance is an important take-away from static analysis.
- **Water level inside the structure:** checking this enable us to find how free-surface level inside is located relative to the outside.

6 Revision comments

Revision no.	Comment
1.0	First publication

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