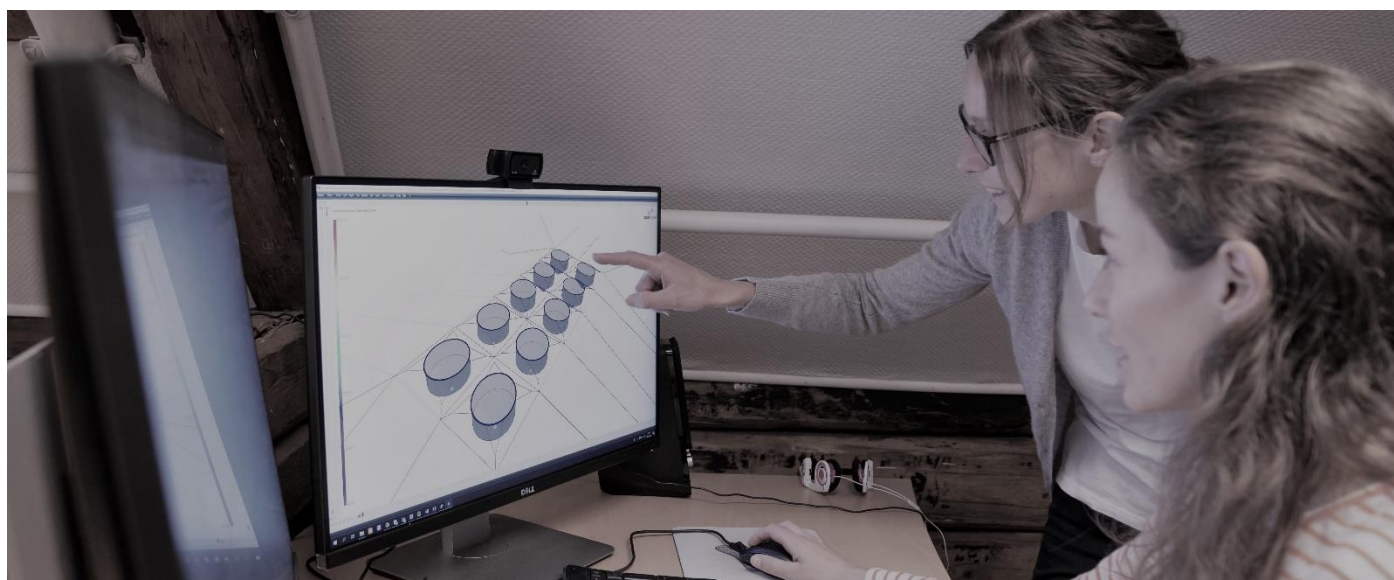


# AquaSim training courses

- Hexagonal Masks



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# 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 Case study – Hexagonal Masks

### 2.1 Learning objectives

In this case study you are presented to:

- The fundamentals of hexagonal shaped masks
- How to generate hexagonal masks in a model
- The input parameters
- Available result options in the post processing tool AquaView

### 2.2 Introduction

Hexagonal shaped masks may in the AquaSim literature be referred to as hex mesh, hex masks, 6-sided membrane or hexagonal masks. These are all name variations of the same feature.

In this case study you should establish a container, or net, with hexagonal masks as illustrated in the figure below. Then a static analysis is performed to demonstrate the result options that is available in AquaView.

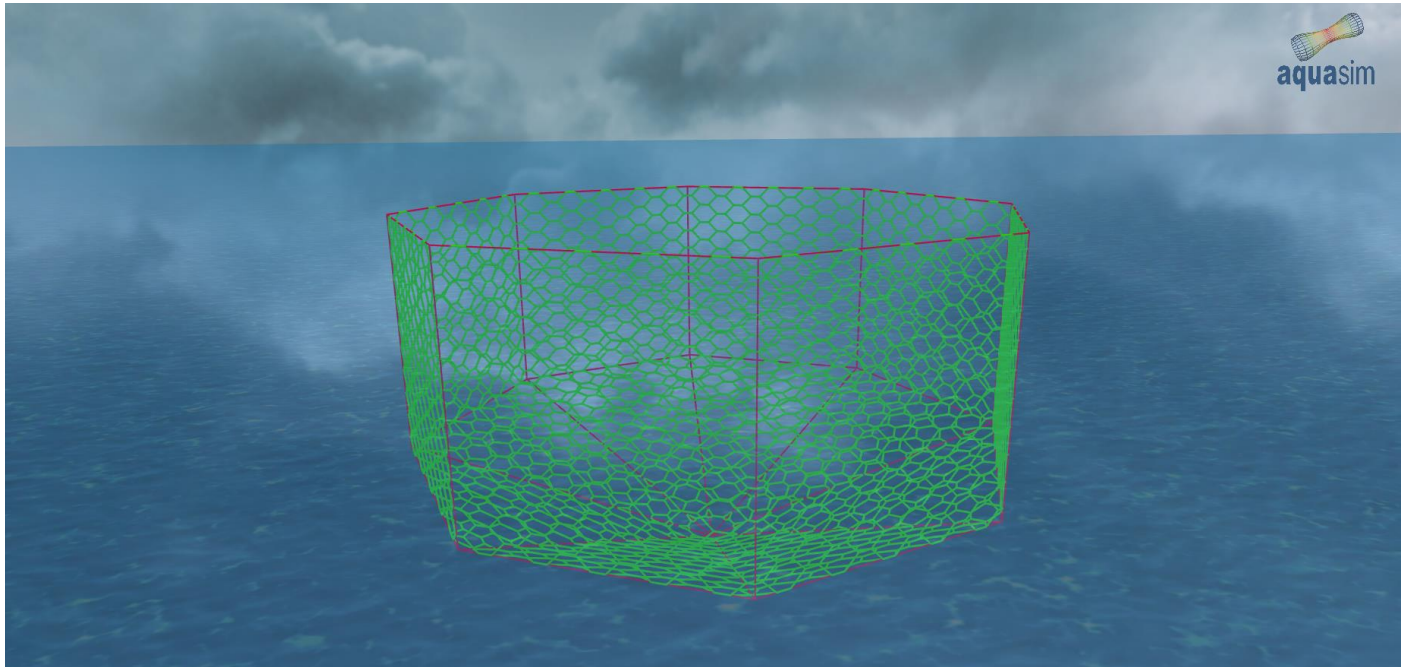


Figure 1

## 2.3 Principles of hexagonal masks

Hexagonal masks are available through the tool **Generate Hex** found in the Tools menu in AquaEdit. Each modelled hexagon will represent smaller hexes, according to the input thread diameter and size of the individual masks. This principle is illustrated in the figure below.

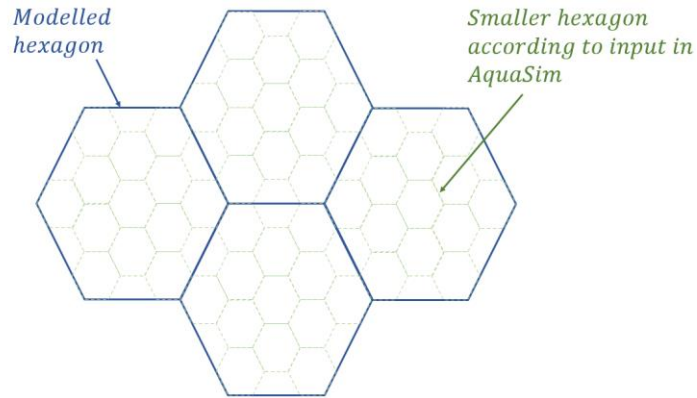


Figure 2

The mesh that hexagonal masks constitute can be compared with traditional hexagonal nets or fences where the wires are regularly twisted together. In AquaSim, the hexagon mask is built up by diagonals and knots as illustrated in the figure below.

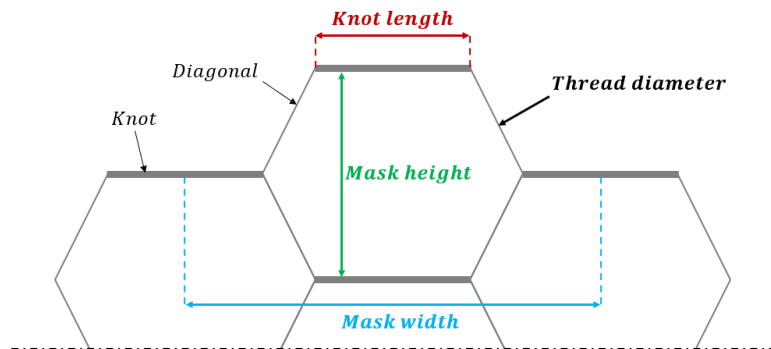


Figure 3

The input to AquaSim is:

- Knot length [mm]
- Mask height [mm]
- Mask width [mm]
- Thread diameter [mm]

The Thread diameter corresponds to the diameter of the Diagonal, and the relation between the diameter of the Knot and Diameter is:

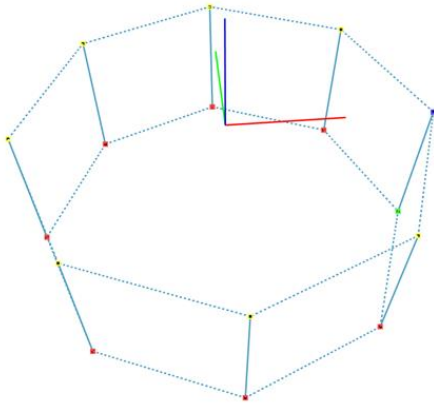
$$d_{knot} = \sqrt{2} \cdot d_{Diagonal}$$

More information about the theoretical formulation of hexagonal masks can be found in this report [TR-FOU-100004-1](#).

### 2.3.1 Modelling principles

To model hexagonal masks one need to first create an outline, or framework, then the masks are generated within this outline.

*Outline*



*Outline and hexagonal masks*

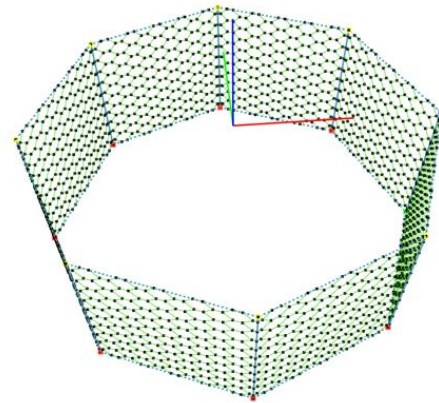


Figure 4

The outline must be created by applying MEMBRANE X. When the masks are created the outline can be deleted from the model, as it has no practical contribution anymore.

Note that AquaSim calculates forces based on the assumption of similarity between the mask sizes and the modelled elements in the 3D window (Norwegian: *formlikhet*). AquaSim tolerates some deviances, but only to a limited extent. Therefore, it is of importance to ensure that size of the modelled elements fairly adds up with the smaller hexes. Help tool to ensure this is provided through the **Fit-** or **Scale** options in the **Generate Hex** tool.

## 2.4 Pre processing

### 2.4.1 Establish outline for hexagonal masks

Load AquaEdit and create an outline with 8 sides and dimensions as described below. The outline should be of the component type MEMBRANE X, and the centre should be situated in the global origin ( $x, y, z$ ) = (0, 0, 0).

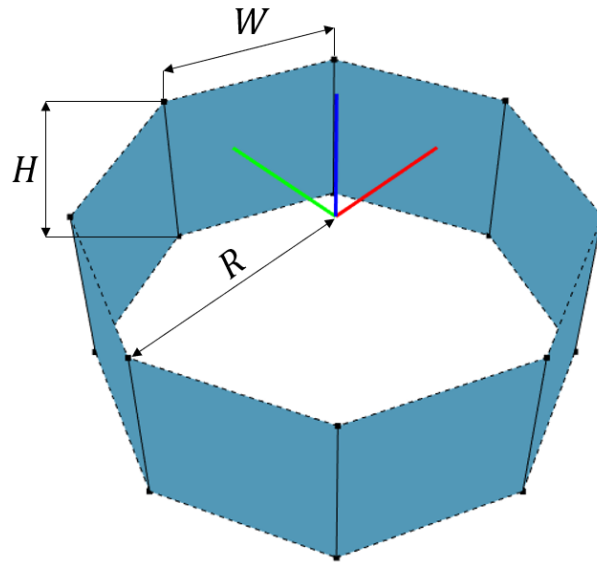


Figure 5

Dimensions of outline	
Radius (R)	26.131 m
Width (W)	20 m
Height (H)	20 m

### Tip!

#### How to generate the 8-sided outline:

Start with a component type TRUSS and generate a circle with 8 segments and radius equal to 26.131m.

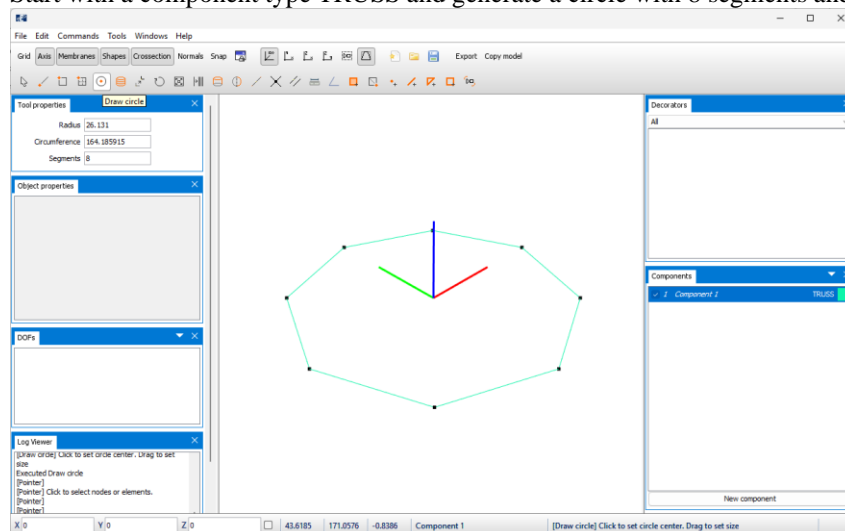


Figure 6

Extrude path 20m in negative z-direction.

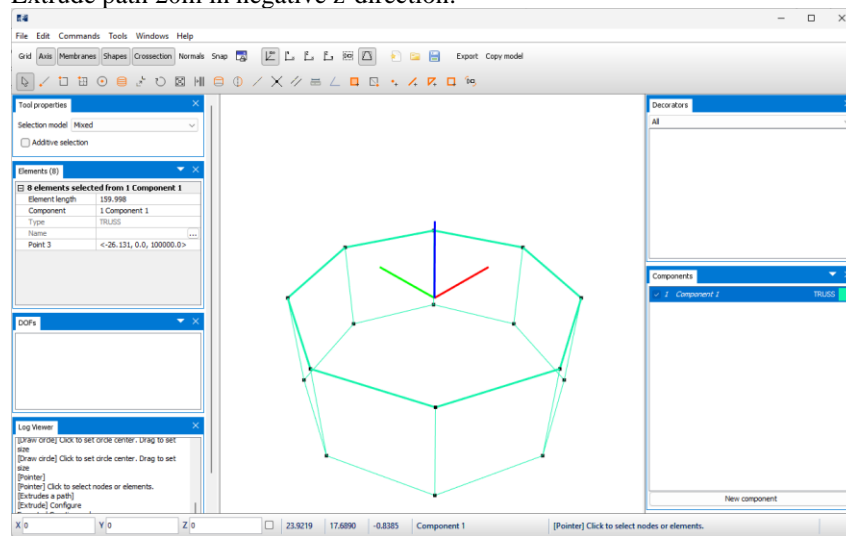


Figure 7

Then change the component type from TRUSS to MEMBRANE, then to MEMBRANE X.

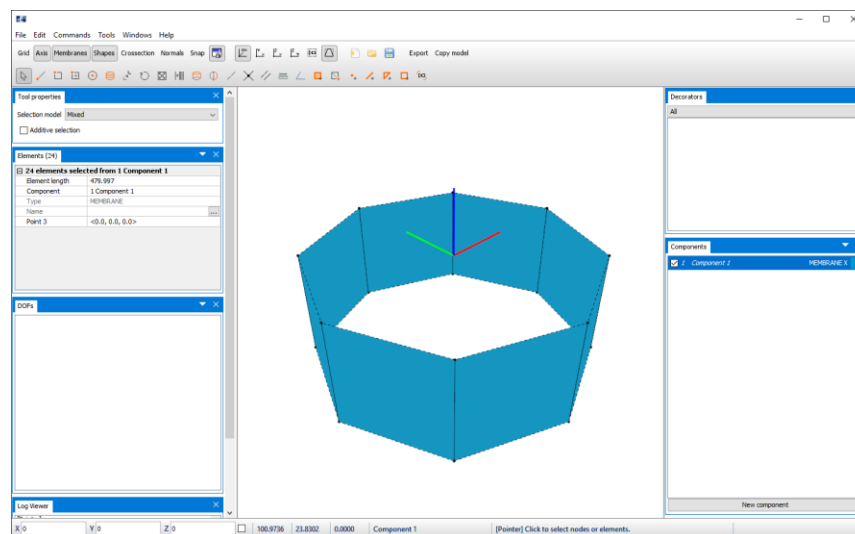
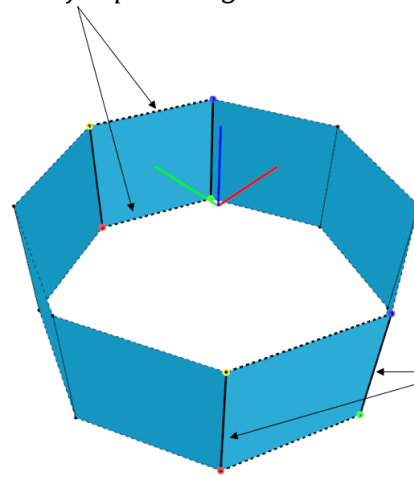


Figure 8



When generating the outline, it is advised that the horizontal elements are as parallel as possible and of equal lengths. This also apply for the vertical elements.

*Horizontal elements is parallel and of equal length.*

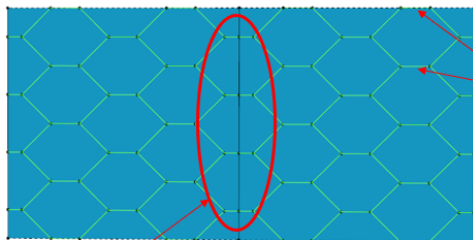


*Vertical elements is parallel and of equal length.*

Figure 9

This is recommended in order to ensure that the masks will coincide between the side surfaces. An example of what is meant by coincidence of the masks and not is illustrated in the figure below.

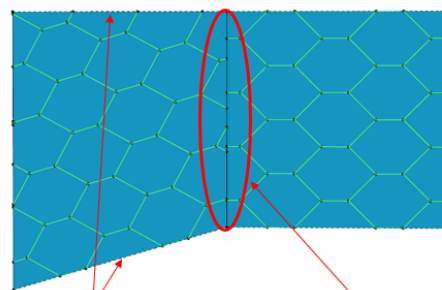
*When horizontal and vertical lines of the outline are parallel:*



*These are parallel*

*The masks between sides matches*

*When horizontal and vertical lines of the outline are not parallel:*



*Not parallel*

*The masks between sides do not match*

Figure 10



## 2.4.2 Generate Hex: sides

In this section, masks on the container sides should be generated. The parts that should be included to generate the masks should be selected. To select MEMBRANE X components, select **Pointer** and from the drop-down menu choose **Quads**.

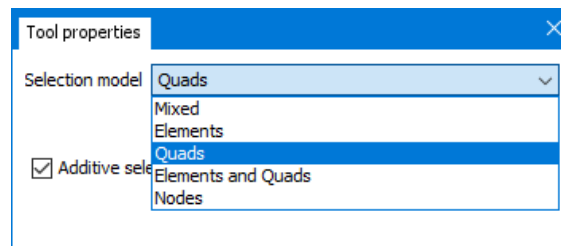


Figure 11

Box-select the outline from the 3D window.

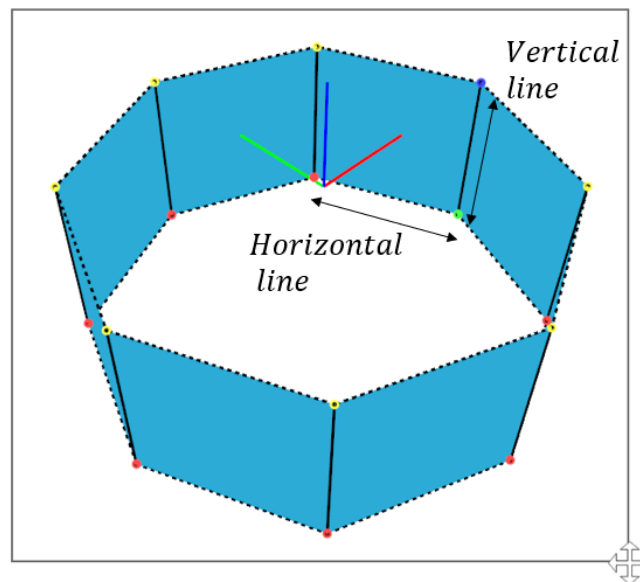


Figure 12

Each corner of the nodes is assigned a colour. Red to green is the first horizontal edge, green to blue is the first vertical edge. Blue to yellow is the second horizontal edge, and yellow to red is the second vertical edge. This is important: the horizontal and vertical lines indicate the direction of the masks.

Go to **Tools > Generate Hex** and select the tab **Membrane**.

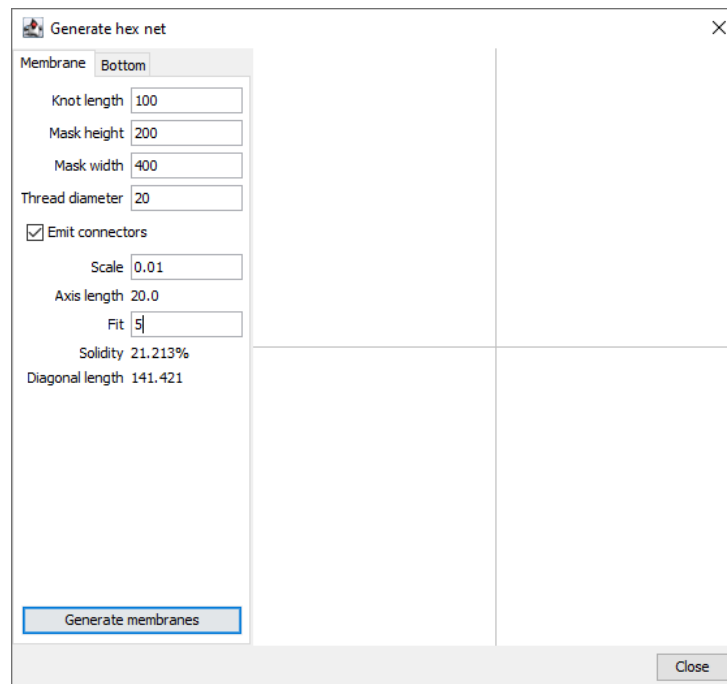


Figure 13

Input parameters for the mask should be:

**Knot length** = 100 mm  
**Mask height** = 200 mm  
**Mask width** = 400 mm  
**Thread diameter** = 20 mm

**Emit connectors:** connectors are truss elements modelled between the edges of the outline. By toggle on, these truss elements are included when generating the masks. We want to include the trusses and leave this option activated.

**Scale:** scale the mask size. This option is dependent on the Fit, so if one adjusts one the other option is updated. We do not make any changes here.

**Axis length:** indicates the length of the edge between the red to green node. That is, the horizontal line.

**Fit:** this is the number of masks that should be generated from the red to green node (horizontal edge). We choose to have 5 masks fitted in the outline, so we type **Fit** = 5.

Select **Generate membranes**. When the masks are generated, you can select **Close** in the Generate Hex window. The model should now resemble the figure below.

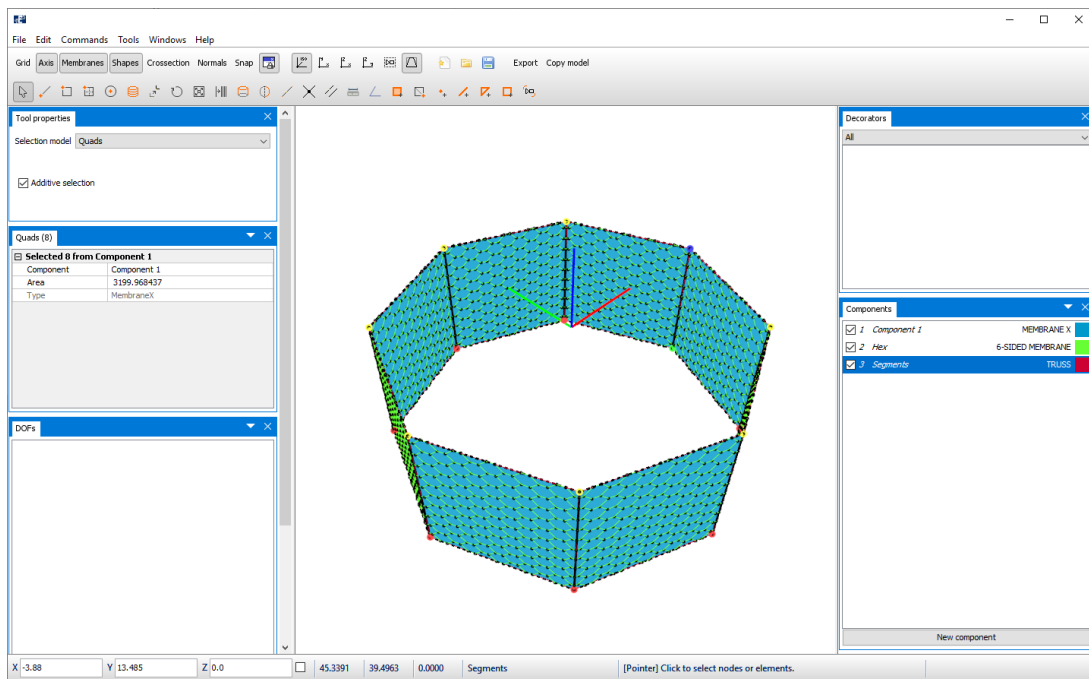


Figure 14

In the Components window you will see that two new component groups are generated: *Hex* and *Segments*. *Hex* is the hexagonal masks and is assigned to the component type 6-SIDED MEMBRANE. *Segments* is generated due to activating the **Emit connectors** in the **Generate Hex**, tool and is component type TRUSS.

### 2.4.3 Generate Hex: bottom

In this section, masks on the container bottom should be generated. The tool Generate Hex provide a tab for generating this. Go to **Tools > Generate Hex** and select the tab **Bottom**.

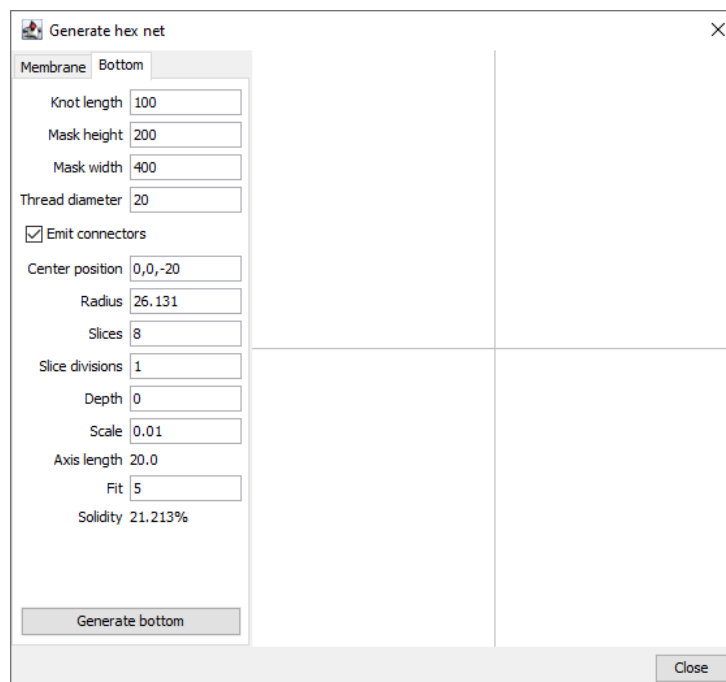


Figure 15

The bottom-masks should have the same properties as the side-masks, we type:

**Knot length** = 100 mm  
**Mask height** = 200 mm  
**Mask width** = 400 mm  
**Thread diameter** = 20 mm

**Center position:** is the coordinates of the centre point for the bottom. The height of the outline was 20 meters; hence we type **0, 0, -20**.

**Radius:** this is the radius of the bottom, measured from Center position. For the bottom to coincide with the lower edge of the sides, the radius should equal the distance from Center position to the lower edge of the sides. From before we know this is **26.131** meters.

**Slice:** is the number of divisions of the bottom. By default, this is 8. In our case we have a total of 8 sides, hence we type **Slice = 8**.

**Slice division:** the number of Slices may be further subdivided with the use of Slice division. Applying e.g., 2 will result in a total of 16 slices when Slice = 8. We only want to have a total of 8 slices, hence: **Slice division = 1**.

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**Tip!**

**The effect of Slice division:**

To illustrate the Slice division, the figure below presents how the bottom would be if Slice=8 and Slice division=1.

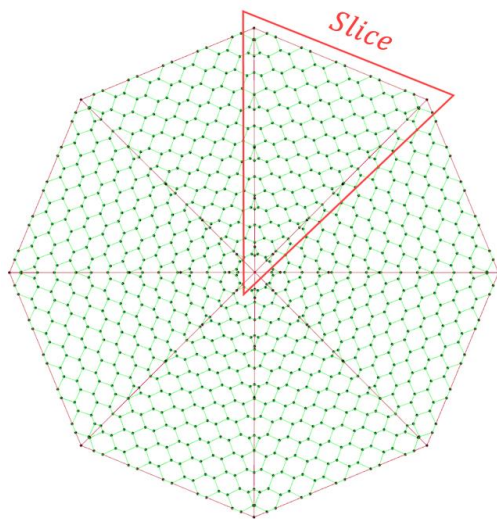


Figure 16

When Slice=8 and Slice division=2.

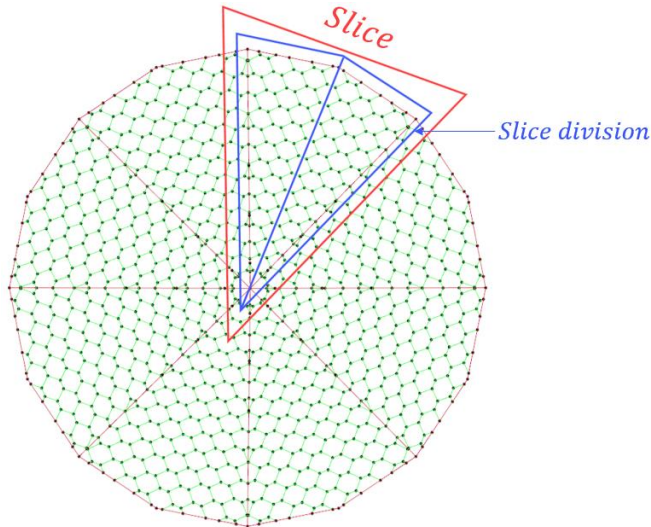


Figure 17

When Slice=4 and Slice division=2.

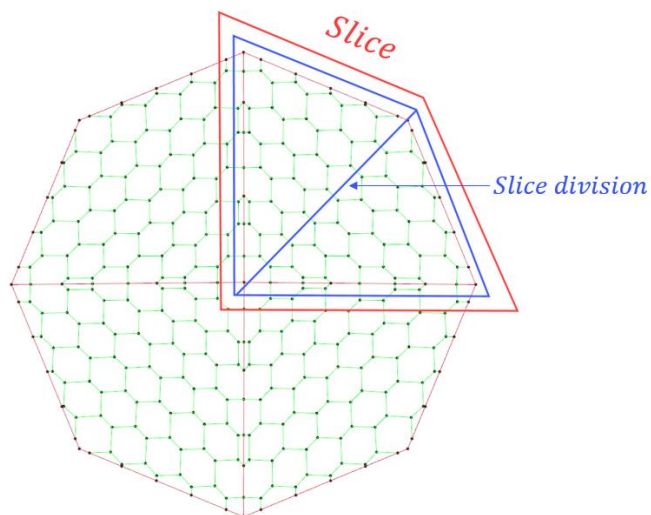


Figure 18

**Depth:** is the depth of the bottom. The depth is calculated with respect to the vertical position specified in Center position. The unit is meters and is measured downwards, meaning that positive values will create a bottom that has a depth in negative z-direction. Our container should have a depth of 10 meters, hence:

**Depth = 10.**

**Scale:** scale the mask size. This option is dependent on the Fit, so if one adjusts one the other option is updated. We do not make any changes here.

**Fit:** this is the number of masks that should be generated from the red to green node (horizontal edge). We choose to have 5 masks fitted in the outline, so we type **Fit = 5**.

Now, select **Generate bottom**. When the masks are generated, you can **Close** the **Generate Hex** window. The model should resemble the figure below.

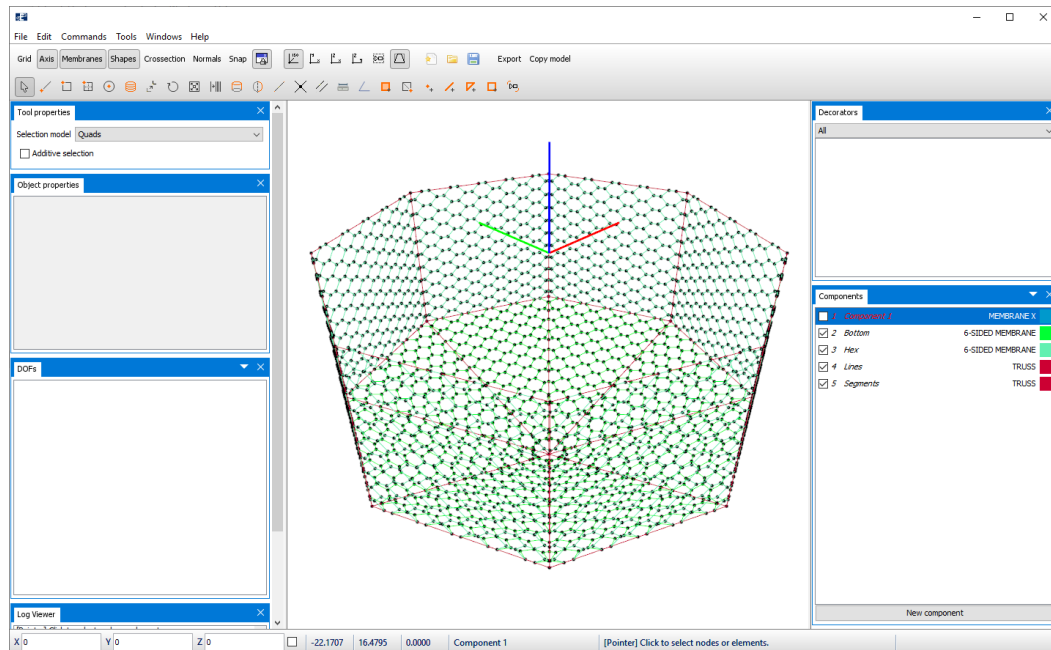


Figure 19

Two new components should have been generated: *Bottom* and *Lines*. Now as the masks are successfully generated, you may delete or deactivate the MEMBRANE X component that were applied as an outline because it is of no use anymore.

#### 2.4.4 Boundary conditions

The model needs some boundary conditions, and in this case study we choose to restrain the top nodes of the container in all Degrees of freedom. Select all the top nodes and select the checkbox to the left in the Nodes window.

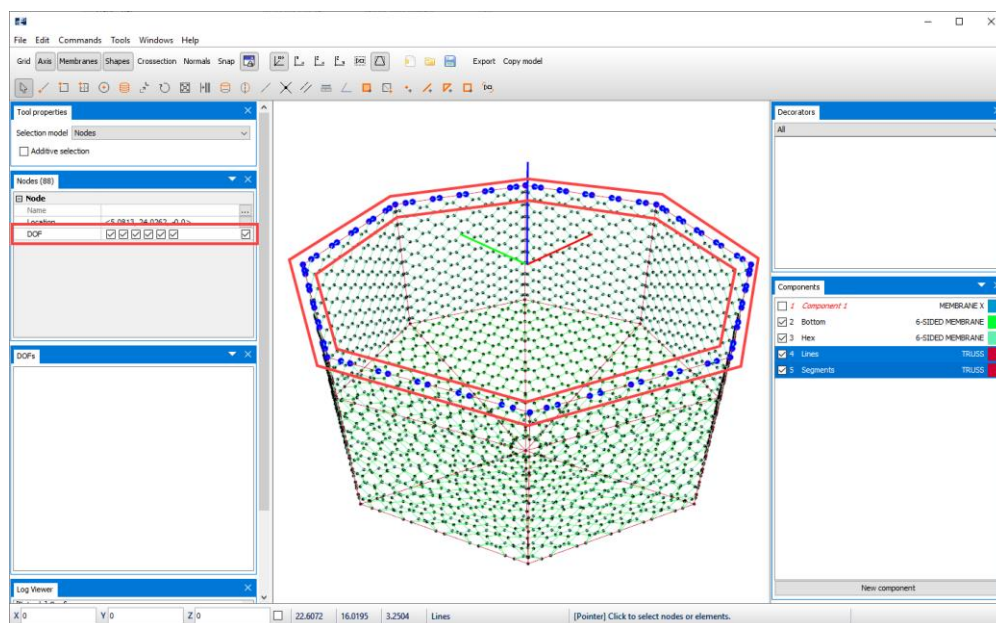


Figure 20

## 2.4.5 Pointload

To suspend the container sides, we add some Pointloads of -300N in z-direction.

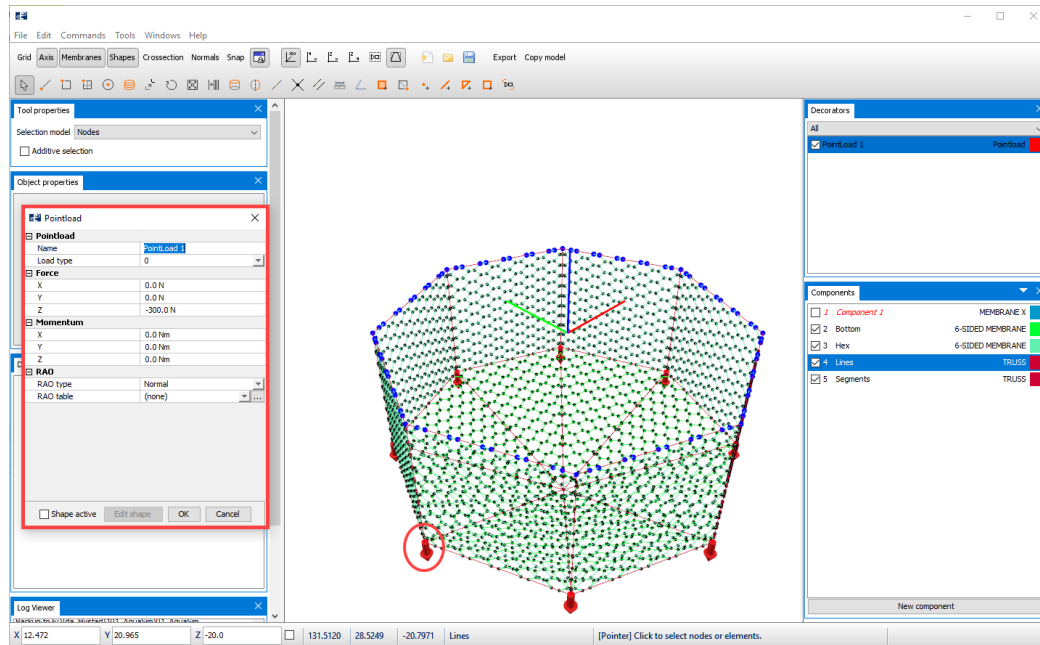


Figure 21

## 2.4.6 Properties of hexagonal masks

We should give the component groups *Hex* and *Bottom* cross-sectional properties. In the components window, **double click** *Bottom* to open the Edit Membrane window. The available Type and Load formulation for 6-SIDED MEMBRANE is Normal. Go to the **Material properties** tab, and insert **Thread diameter** = 0.02 m, this corresponds to the thread diameter of the Knot.

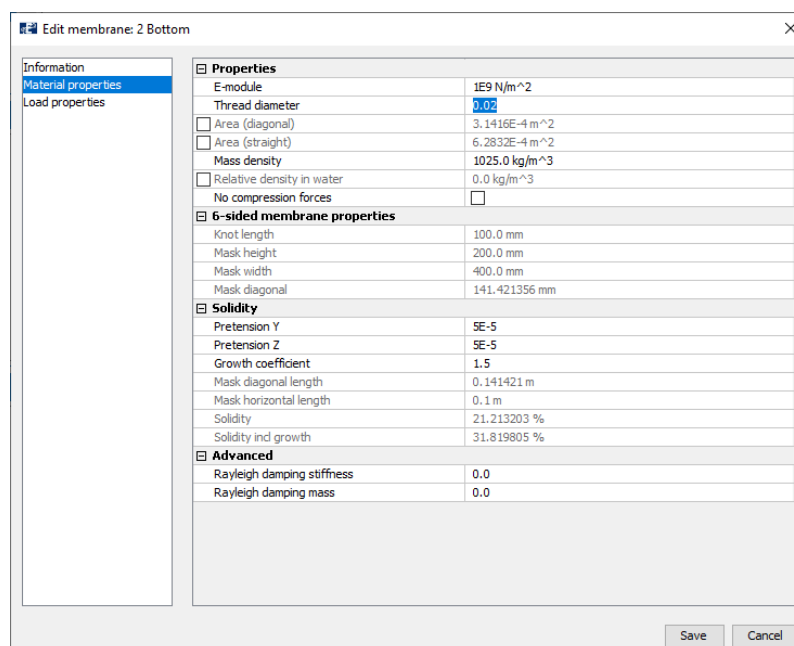
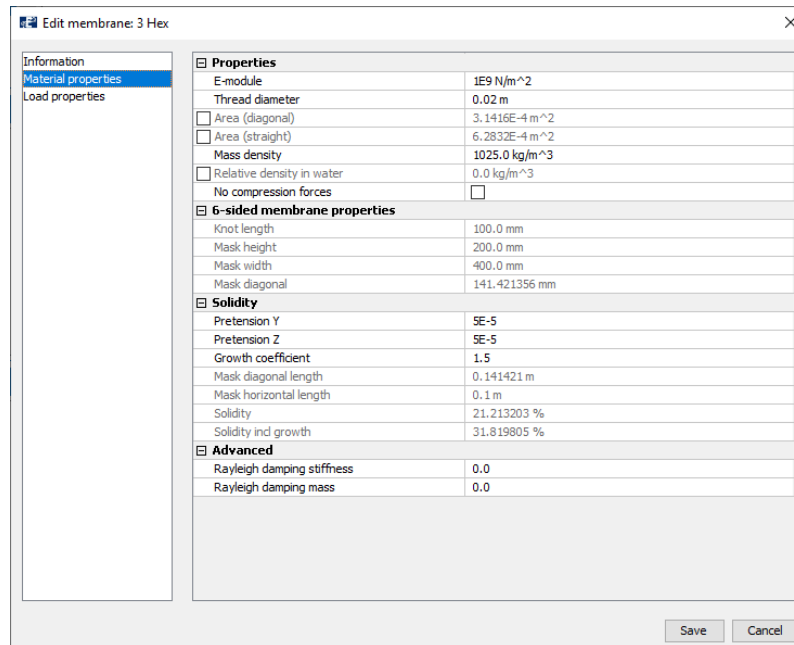


Figure 22



We are satisfied with the parameters and select **Save**.

Enter the Edit membrane window for the component *Hex* and go to the **Material properties** tab and make sure that the parameters correspond to the figure below. The select **Save**.



Edit membrane: 3 Hex	
<div> <div> Information  <b>Material properties</b>  Load properties </div> <div> <div>Properties</div> <div> E-module: 1E9 N/m<sup>2</sup>  Thread diameter: 0.02 m  <input type="checkbox"/> Area (diagonal): 3.1416E-4 m<sup>2</sup>  <input type="checkbox"/> Area (straight): 6.2832E-4 m<sup>2</sup>  Mass density: 1025.0 kg/m<sup>3</sup>  <input type="checkbox"/> Relative density in water: 0.0 kg/m<sup>3</sup>  <input type="checkbox"/> No compression forces: <input type="checkbox"/>  <div>6-sided membrane properties</div> Knot length: 100.0 mm  Mask height: 200.0 mm  Mask width: 400.0 mm  Mask diagonal: 141.421356 mm  <div>Solidity</div> Pretension Y: SE-5  Pretension Z: SE-5  Growth coefficient: 1.5  Mask diagonal length: 0.141421 m  Mask horizontal length: 0.1 m  Solidity: 21.213203 %  Solidity incl growth: 31.819805 %  <div>Advanced</div> Rayleigh damping stiffness: 0.0  Rayleigh damping mass: 0.0 </div> </div> </div>	

Figure 23

## 2.4.7 Properties of Segments and Lines

The truss components *Segments* and *Lines* are assigned cross sectional properties corresponding to the table below.

<i>Segments and Lines</i>	
<b>E-modulus</b>	2.1E9 N/m <sup>2</sup>
<b>Area</b>	3.8E-4 m <sup>2</sup>
<b>Weight in air</b>	0.48 kg/m
<b>Diameter Y / Z</b>	0.022 / 0.022 m
<b>Drag coefficient Y /Z</b>	1.2 / 1.2
<b>Added mass coefficient Y /Z</b>	1.0 / 1.0

## 2.4.8 Verify the model

To check that the model is correct and without errors, you should check the model through **Commands > Verify model**.

You might, depending on your settings, get a warning for close nodes. Then you should check if there are some nodes that should have been merged.



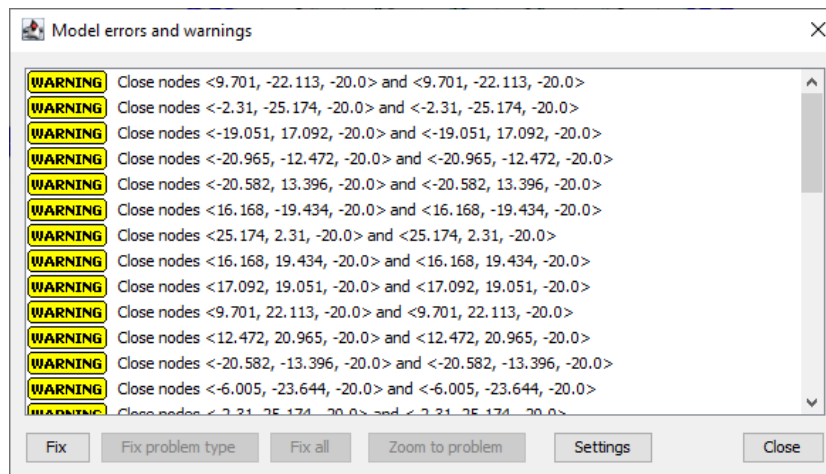


Figure 24

## 2.5 Calculations static analysis

Go to the **Export** menu and select the **Normal** tab, we should conduct a static analysis. Apply the parameters as shown in the figure below.

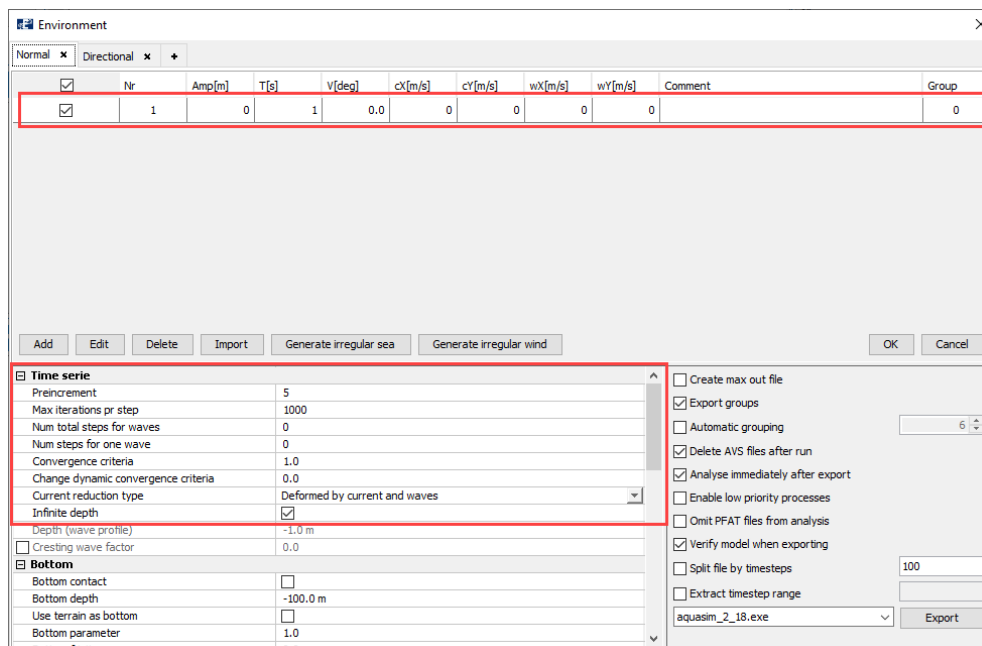


Figure 25

**Export** the model and start the analysis.

## 2.6 Post processing static analysis

When the analysis is finished, open the result-file in AquaView. That is the .avz-file. From the **Result** menu you can select **Net**.

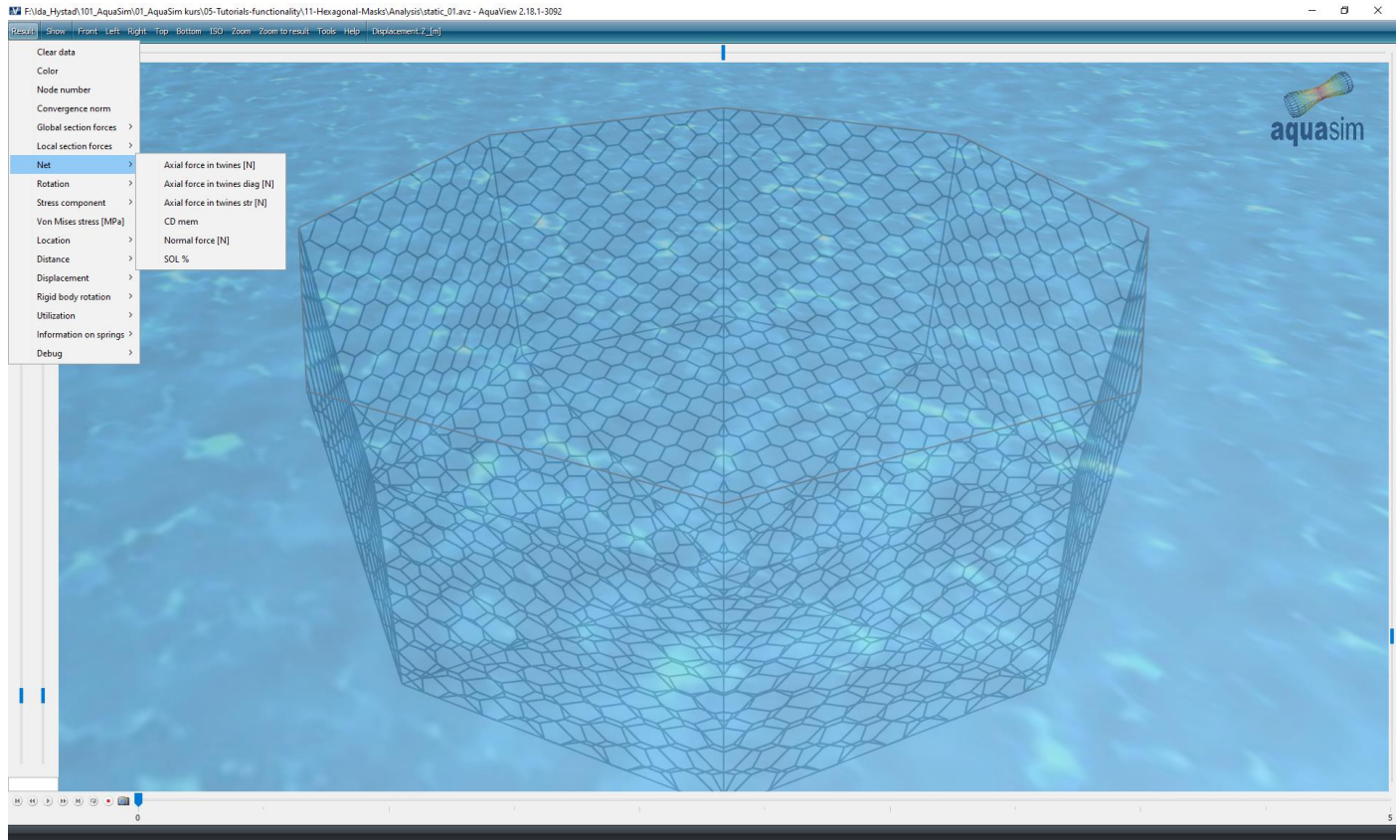


Figure 26

**Axial force in twines [N]:** view axial force in both the Diagonal and Knot threads, shown at det same time.

**Axial force in twines diag [N]:** view axial force in the Diagonals.

**Axial force in twines str [N]:** view axial force in the Knots.

**CD mem:** is the drag coefficient of the hexagonal masks.

**Normal force [N]:** view the force in the ‘visible’ threads on the membrane panel the hexagonal masks constitute. That is, the force summed over the number of threads it represents.

**SOL %:** the solidity of the membrane panel the hexagonal masks constitute.

## 2.7 Summary

In this case study, you have been introduced to how hexagonal masks can be modelled in AquaSim. A container with a bottom has been modelled, cross sectional properties have been added and a static analysis is run. Further, some options for viewing results in AquaView is presented.

### 3 Revision comments

Revision no.	Comment
1.0	First publication

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