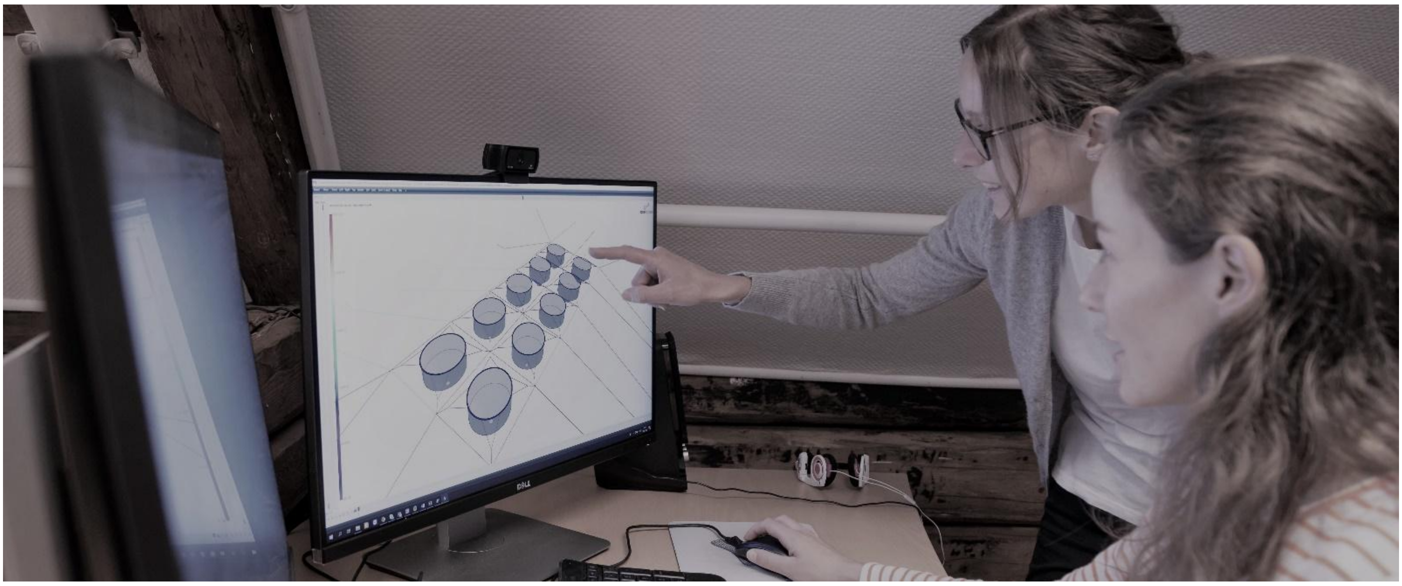
AquaSim training courses

- **Lice skirt**



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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:

- Basic concept of lice skirt
- Lice skirt parameters in AquaSim
- Key result parameter in AquaView

3 Introduction

Salmon lice is a small parasite that is found in marine environment. It is a challenge for the aquaculture industry as it damages the salmon in terms of wounds and infections. A wide range of methods and devices has been developed through the time, to reduce the risk of infections in at the aquaculture facilities – lice skirts are one of them.

The lice thrive in the upper part of the water column, approximately down to 5-10 meters depth. The basic concept behind the lice skirt is to create a barrier between the salmon and the parasite in the part of the water column where the lice lives. If the parasite does not find a host, it will eventually die. The thought is that the lice skirts are permanently installed at the cages as a preventive measure.

Consider a conventional circular aquaculture cage with a net. The lice skirt is installed on the outside of the fish barrier and is attached to the floating collar. The skirt is commonly made by dense, water-resistant fabrics such as tarpaulins in P V C. In this tutorial you will be presented to the basic input-parameters when modelling a lice skirt – what they mean and how they can be applied. Some trouble-shooting aspects and suggested solutions are also included.

The user may find additional information and details on definitions and theory in these reports (Aquastructures, 2025a) (Aquastructures, 2025b).

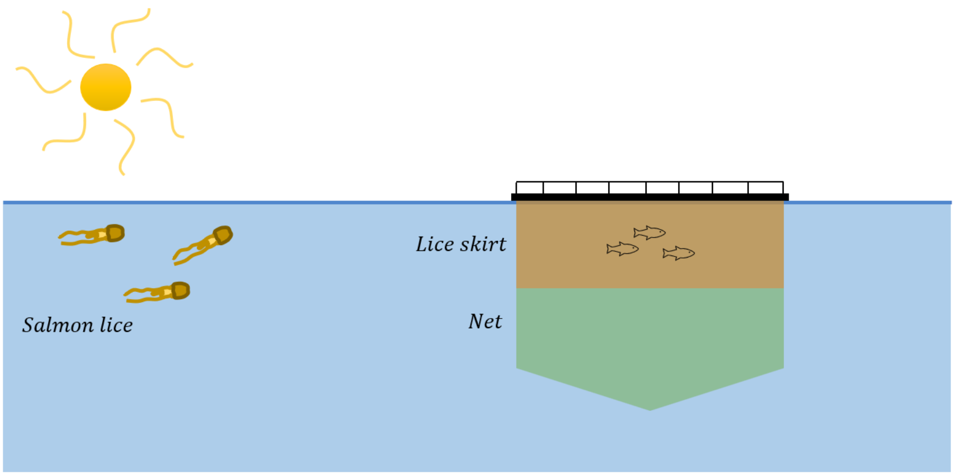

Figure 1

4 Hydrodynamical principles

Let’s consider this from a hydrodynamical perspective. Conventional barriers such as nets have openings allowing water to flow through more or less unhindered.

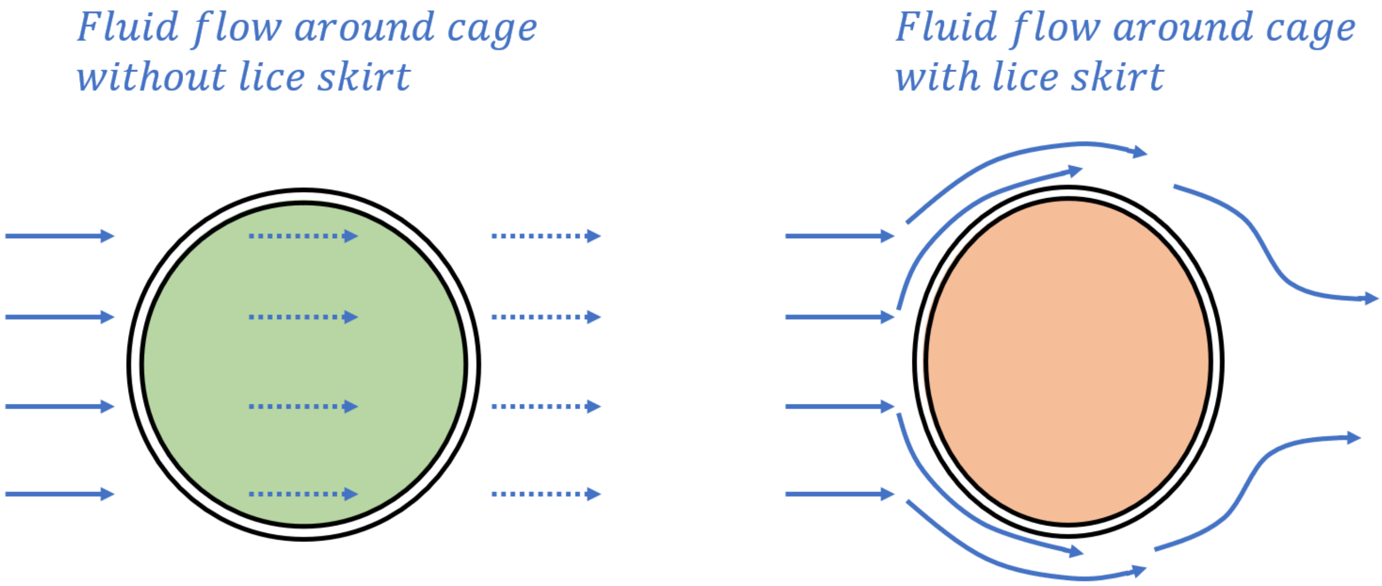

Figure 2

Introducing a lice skirt, the water particles are hindered from flowing through, and must pass on the sides of the barrier, or below. Waves that interact will be accompanied by diffraction and deformation of the lice skirt. Diffraction is the process where waves spread perpendicular to the direction of wave propagation. These effects will cause an increased pressure on the upstream side, and the lice skirt will be deformed. This is commonly known as hydroelasticity – a time-dependent effect, where structures deform under the influence of fluids.

The pressure-increase on the upstream side of the skirt will be transferred to the cage, and in turn lead to increase loads in the anchoring system. This is something to be aware of when planning an anchoring system at a fish farm facility.

5 Modeling principles

5.1 Pressure distribution and component groups

To model lice skirts in AquaSim, one can apply load formulation **Lice skirt** for the component type Membrane X (or Membrane).

AquaSim assumes that lice skirts always are modelled as a cylinder. Which membrane panels are upstream of waves and current, and which panels are downstream are kept track of. By this, AquaSim is able to distribute the pressure field around the lice skirt in a realistic manner. To illustrate this pressure field, let us simplify the problem and consider fluid flow around a cylinder. Upstream it will experience pressure drag force, and downstream suction drag. On the upper and lower sides, the cylinder will experience lift forces.

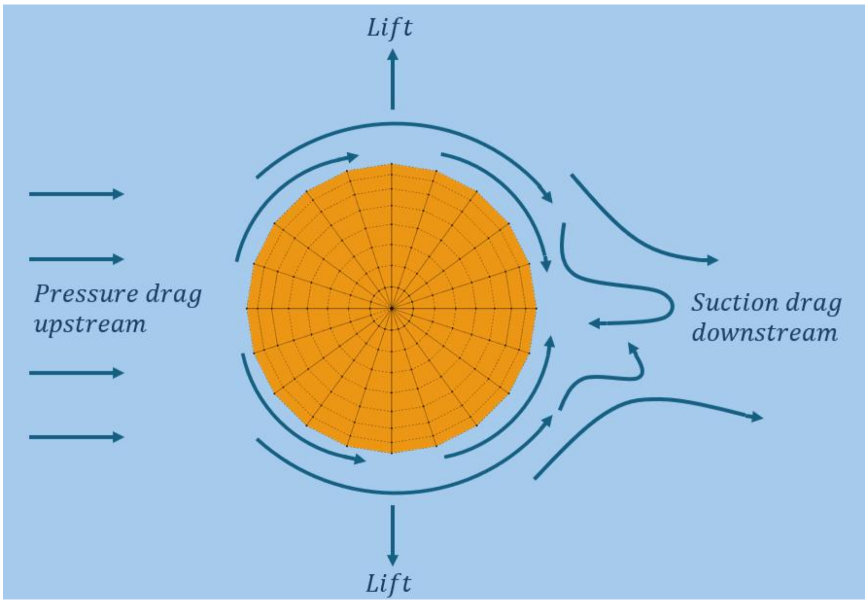

Figure 3 Pressure distribution around a circular structure

A consequence of AquaSim being able to keep track of what is upstream and downstream, is that each lice skirt must be modelled as its own component group. If you for example have a model of an aquaculture facility with 2 by 2 cages, you will need to model the lice skirts in 4 individual component groups. This is illustrated below.

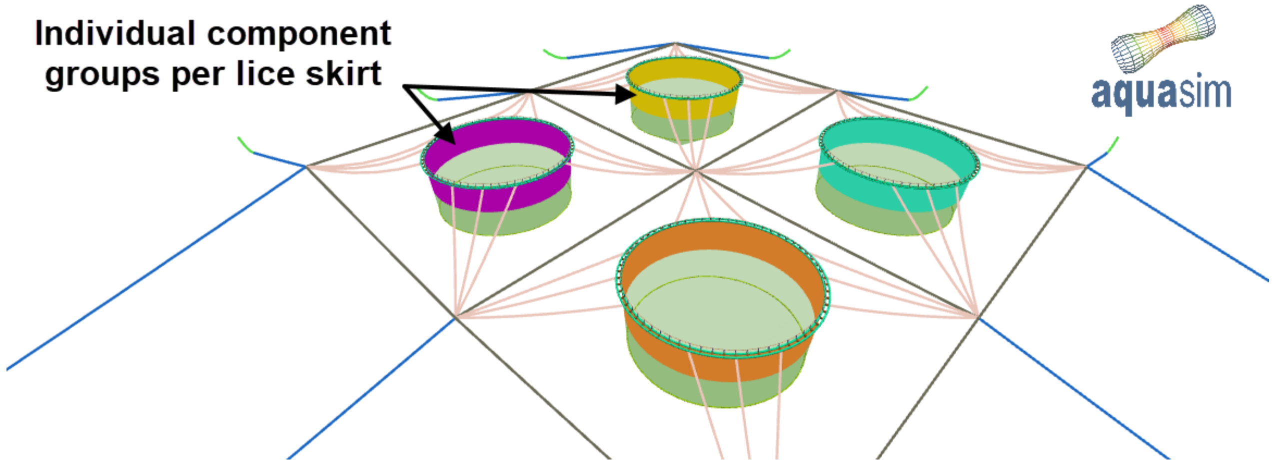

Figure 4

5.2 Inside and outside definition of lice skirt

When working with models with enclosed volumes it is important to keep track of what is considered the inside and outside of the volume. This is because AquaSim facilitates defining hydrostatic- and dynamic parameters for the fluid within the enclosed volume and outside.

When considering the local coordinate system of a membrane panel, the normal vector (blue line) should point into the interior of the volume. This is indicated in the figure below.

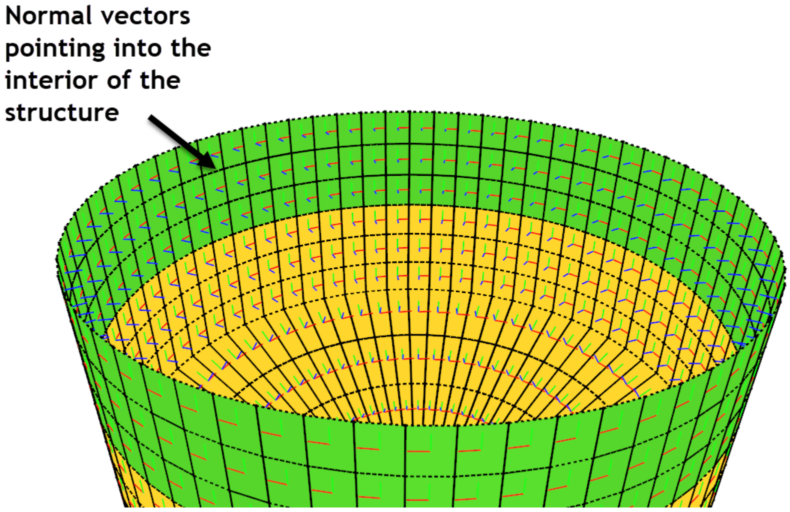

Figure 5 Normal vectors (small blue lines) pointing into the interior of the structure

Another useful tool to verify the orientation of the panel normals, is to apply the function *Membrane side* found in AquaEdit. Where the side that faces out towards the external fluid will be colored with a shade of blue, and the sides facing towards the interior will be colored with a shade of red. This is illustrated below.

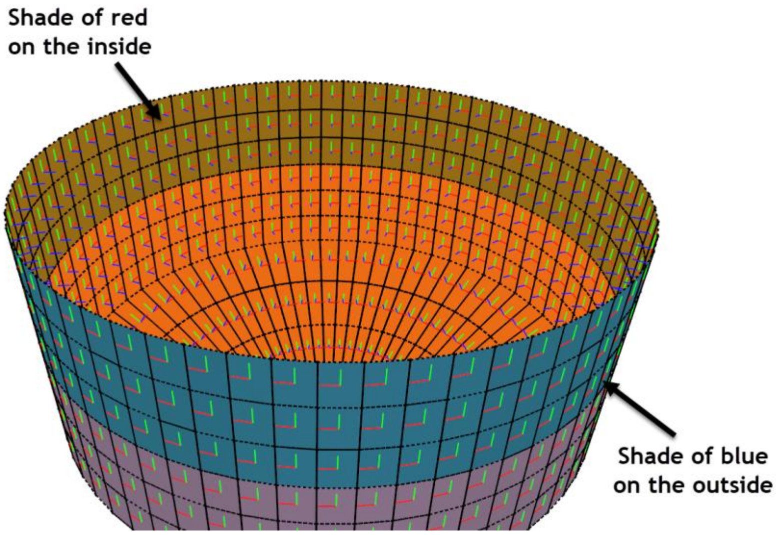

Figure 6 Membrane side in AquaEdit

6 Case study – Lice skirt

6.1 Lice skirt

For the next steps, you may use the AquaSim model *LiceSkirt.amodel*, following this tutorial. You are to finish the model by inputting appropriate parameters to the lice skirt.

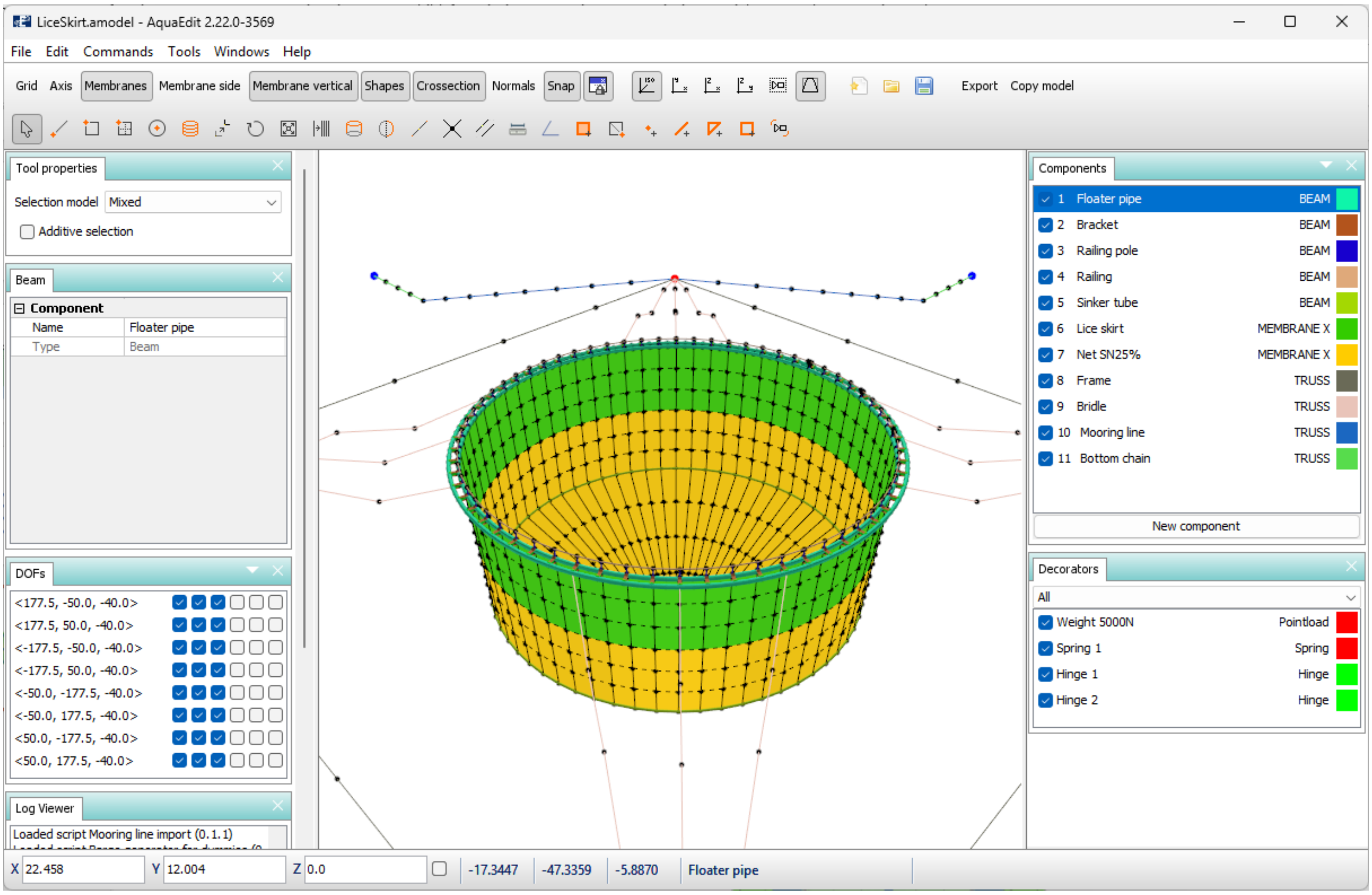

Figure 7

The model contains a classical configuration with a PE floating collar and a permeable net mounted in a frame anchoring system. Attached to the net, is the lice skirt. The lice skirt is modelled with membrane type *Normal* in combination with Load formulation *Lice skirt*.

Double click on the component type *6 Lice skirt*, in the components window, and navigate to the **Load properties** tab. This tab provides input parameters that is relevant for the type of dense fabrics as lice skirt.

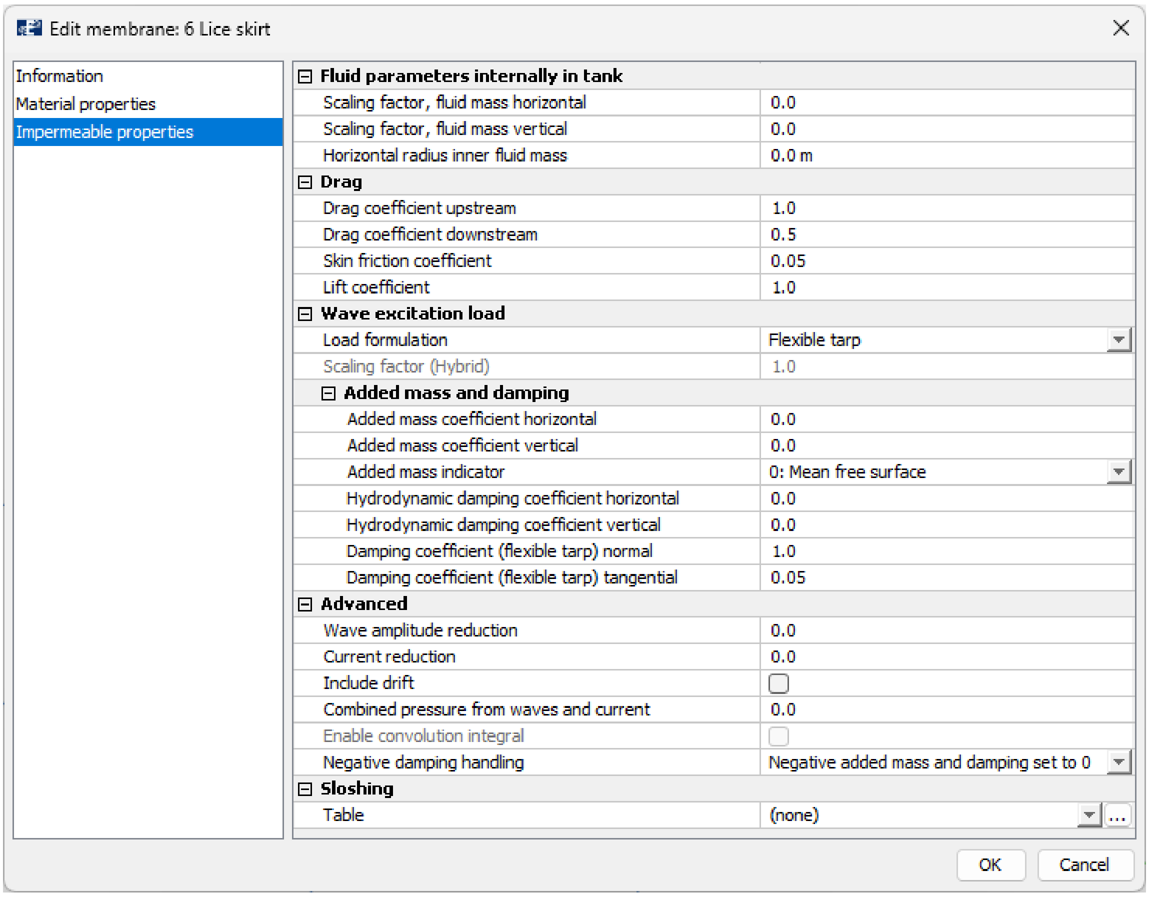

Figure 8

In the next sections, the different parameters are presented – what they mean and how they can be used. Please note that the values of the presented input-parameters are not definitive requirements. It is acknowledged that there is very limited empirical data available for these types of structures. So, the user must also assess the values based on experience with expected response of the tarpaulin and load distribution. The presented values should be treated as indicative guidance rather than fixed recommendations.

Because empirical data is limited, a degree of uncertainty must be expected. However, the uncertainty may me reduced by considering a range of values for the parameters by conducting sensitivity studies and evaluate how the different parameters influence the overall response and load distribution on the tarpaulin.

6.2 Fluid parameters internally in tank

The *Fluid parameters inside tank* specifies the properties of the fluid enclosed by a structure. These parameters define how much of the fluid that should be set into motion when the structure is exposed to waves and current.

For lice skirts these parameters is recommended to be set to **0.0**. This is because a lice skirt does not trap or confine any internal fluid. The bottom is open through the permeable net below, so the fluid is free to move. These parameters become relevant in the case of fully or partially closed volumes.

6.2.1 Drag

This part of the *Impermeable properties* regulates the magnitude of pressure drag, skin friction drag and lift forces acting on the lice skirt. Before discussing these coefficients, it is useful to understand how the fluid flow behaves when it passes the skirt.

The figure below illustrates the lice skirt seen from above. When fluid flow approaches the lice skirt, it meets a solid barrier. On the upstream side, the fluid slows down and creates a high-pressure region. This is where the largest drag force occurs. As the flow moves around the sides of the skirt, it will start to accelerate along the surface, which will increase the skin friction drag.

Further downstream, the fluid cannot stay attached to the surface any longer and it separates. A region of turbulent wake is created behind the skirt. In this wake region the fluid loses momentum, and energy is dissipated into turbulence, leading to a low-pressure region. This is why suction drag downstream is smaller than the pressure drag on the upstream side.

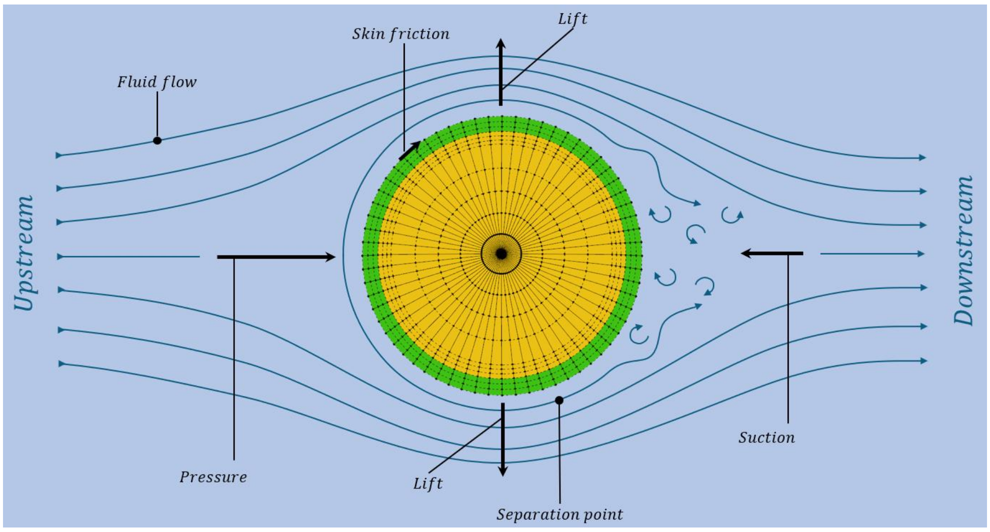

Figure 9 Upstream and downstream definition

Since AquaSim keeps track of where the panels are situated with respect to each other, it is possible to assign drag coefficients upstream and downstream with respect to incoming wave and current.

6.2.2 Drag coefficient upstream

AquaSim decompose the relative velocity (between the lice skirt and fluid) into a normal and tangential component, as illustrated below. The normal component of the relative velocity is applied in the calculation of pressure drag. The *Drag coefficient upstream* scales this force for panels located upstream.

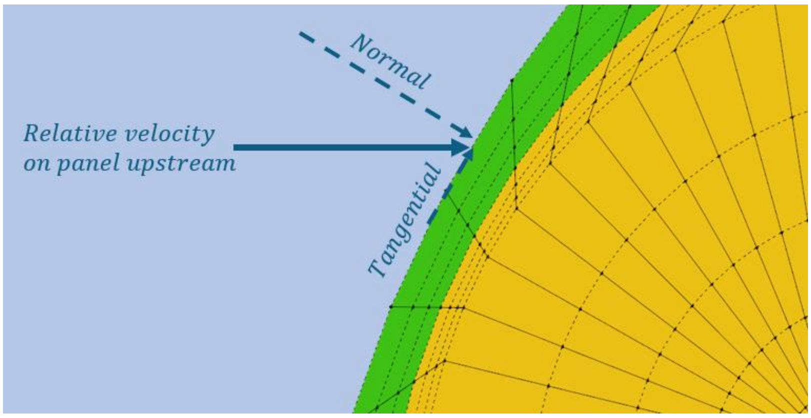

Figure 10 Normal component of relative velocity between fluid flow and lice skirt upstream

In this case, this parameter is set to **1.0**.

6.2.3 Drag coefficient downstream

As mentioned above, AquaSim decompose the relative velocity into a normal and tangential component. The normal component of the relative velocity downstream is applied in the calculation of suction drag. The *Drag coefficient downstream* scales this force for panels located downstream.

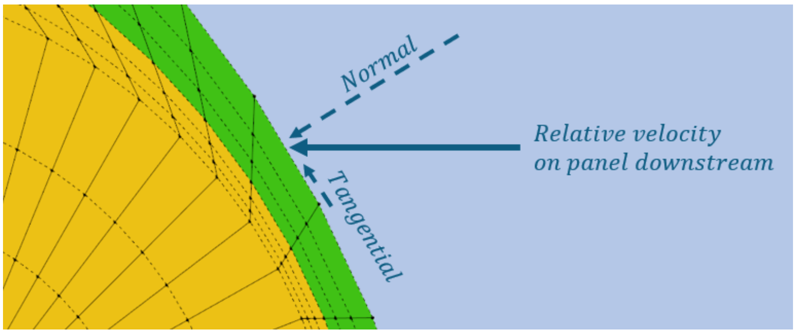

Figure 11 Normal component of relative velocity between fluid flow and lice skirt downstream

In this case, this parameter is set to **0.5**. The drag coefficient downstream on the lice skirt is lower than the upstream because of flow separation. When the flow passes the impermeable lice skirt, the flow will separate. The consequence is that the fluid loose momentum, which results in reduced pressure on the downstream panels.

6.2.4 Skin friction coefficient

Skin friction force arises due to fluid particles tend to “stick” to the surface. The magnitude of this force often depends on fluid viscosity and surface roughness. The *Skin friction coefficient* regulates the magnitude of the skin friction force. In AquaSim this force is calculated applying the tangential relative velocity.

In this tutorial, skin friction coefficient is set to **0.05**.

6.2.5 Lift coefficient

The *Lift coefficient* scales the lift force that acts perpendicular to the fluid flow direction. Lift force arises when a flow around a structure is asymmetric, creating a pressure difference between structure sides. AquaSim apply the normal component of the relative velocity, as well as the total relative velocity, to calculate the lift force on a panel.

In our case, the Lift coefficient is set to **1.0**.

6.3 Wave excitation load

This section presents the input parameters for wave induced forces. AquaSim provides several methods for how this can be calculated, based on the rigidity of the investigated structure. Some of the methods are adapted to highly flexible structures, other for rigid-body structures, and semi-rigid structures.

6.3.1 Load formulation

A load formulation defines how the wave induced forces should be calculated. As lice skirts are made of flexible tarpaulin fabric, the load formulation *Flexible tarp* is selected. *Flexible tarp* are adapted to flexible woven textiles that to a high extend follow the fluid particle motion. It is assumed that diffraction forces due to scattering of waves are negligible in this load formulation, such that only Froude-Kriloff pressure is included here.

6.3.2 Scaling factor (Hybrid)

This parameter is available when one of the two hybrid load formulations are selected. So, for this case this parameter is not relevant.

6.4 Added mass and damping

Added mass is an inertia force that arise because water has mass, and this mass resists changes in motion. When a structure accelerates in water, some of this water must also accelerate with the structure, both vertically and horizontally. Damping is the force that resist the relative motion between the structure and surrounding water. This causes the structure to have lower response.

The *Added mass coefficient horizontal*, *Added mass coefficient vertical*, *Hydrodynamic damping coefficient horizontal* and *Hydrodynamic damping coefficient vertical* should all be set to **0.0**. This is because the Flexible tarp model already includes its own internally calculated inertia and damping effects. Adding Morison-type coefficients on top of that will double-count these forces. These parameters should be accounted for when applying *MacCamy-Fuchs* or *Numerical diffraction* models.

6.4.1 Damping coefficient (flexible tarp) normal

This is a type of damping that regulates the response of the lice skirt, meaning how much the skirt should follow the fluid particle motion. It is applied locally on each panel, in normal direction. A value of 1.0 corresponds to a condition where the panel motion follows the wave particle motions, implying that there is no relative motion between the panel and the surrounding fluid in normal direction.

In this tutorial, the *Damping coefficient (flexible tarp)* normal is set to **1.0**. This corresponds to applying 100% of the damping that AquaSim calculates.

Please note that this parameter should not be confused by the *Hydrodynamic damping coefficient*, which represents Morison damping and is not based on relative velocity between the skirt and fluid. The *Damping coefficient (flexible tarp)* is a built-in damping effect on the lice skirt deformation (or response).

6.4.2 Damping coefficient (flexible tarp) tangential

This parameter also regulates the response of the lice skirt, but tangential to each panel. The *Damping coefficient (flexible tarp) tangential* is derived from the damping in normal direction. Generally, this damping is considered small compared to the normal direction. For numerical stability of your analysis, you should apply a damping in this direction as well.

This parameter is set to **0.05**, meaning 5% of the damping found in normal direction is applied tangential to each membrane panel.

6.5 Advanced

The Advanced section provides parameters to modify how environmental loads from waves and current should be applied to the structure. These options allow the user to adjust or refine the hydrodynamic load model beyond the standard methods.

Parameters found here is outside the scope of this tutorial. So, it is not further discussed. More information about this is found in (Aquastructures, 2025b) and (Aquastructures, 2025c).

6.6 Sloshing

Sloshing is oscillatory motions of a free surface inside an enclosed volume. Sloshing requires a more or less enclosed volume with rigid boundaries that allow the internal water to oscillate. A lice skirt is open at the bottom, so the water cannot be trapped. So, no standing sloshing mode can be formed in this case study. Therefore, sloshing is not considered in this tutorial.

6.7 Analysis

Now that you are introduced to the different parameters and what they mean, we should run an analysis and then have a look at key result parameters in AquaView.

A load condition is prepared, go the **Export** and the tab **Normal**. A wave amplitude of 1.4 meters and -period of 4 seconds is applied. Also, current along x-direction is used.

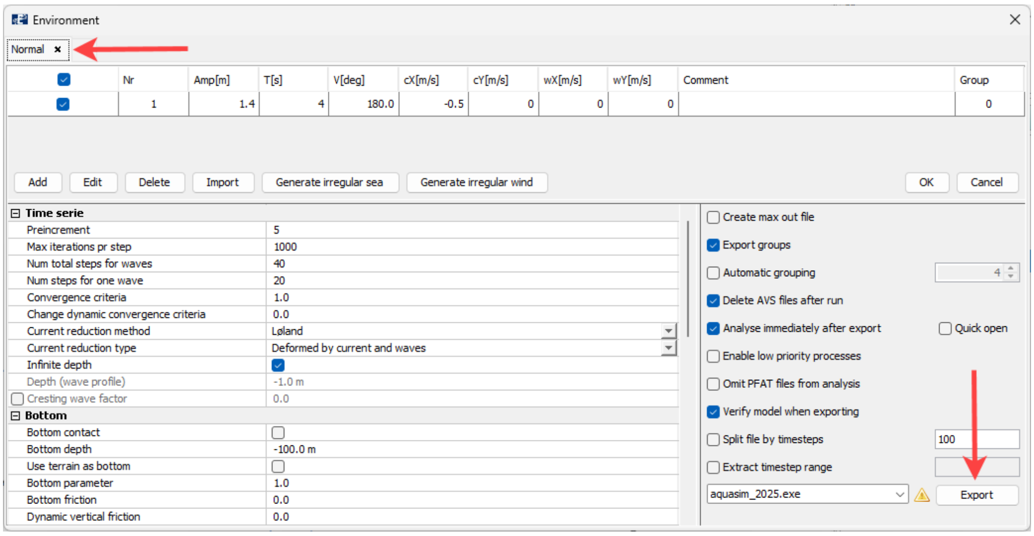

Figure 12

Since we are working with *Membrane X*, remember to check that *Membrane normals are verified* is activated. This option 'lock' the orientation of the membrane normals. If this is not selected, you risk that AquaSim automatically change the orientation.

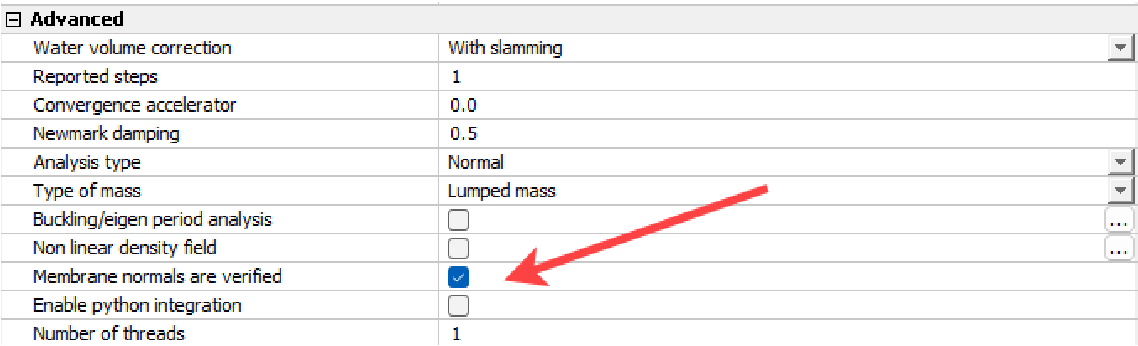

Figure 13

Export the model and start the analysis. This analysis will take 5-8 minutes to complete, depending on your computer capabilities. We named the analysis *liceskirt_*.

6.8 Post processing

Load the result-file, the one that ends with .avz. If you have not run your own analysis, you may open the *liceskirt_01.avz* that is associated with this tutorial.

Impermeable nets, such as lice skirts are in AquaView viewed as a membrane but with a darker rendering.

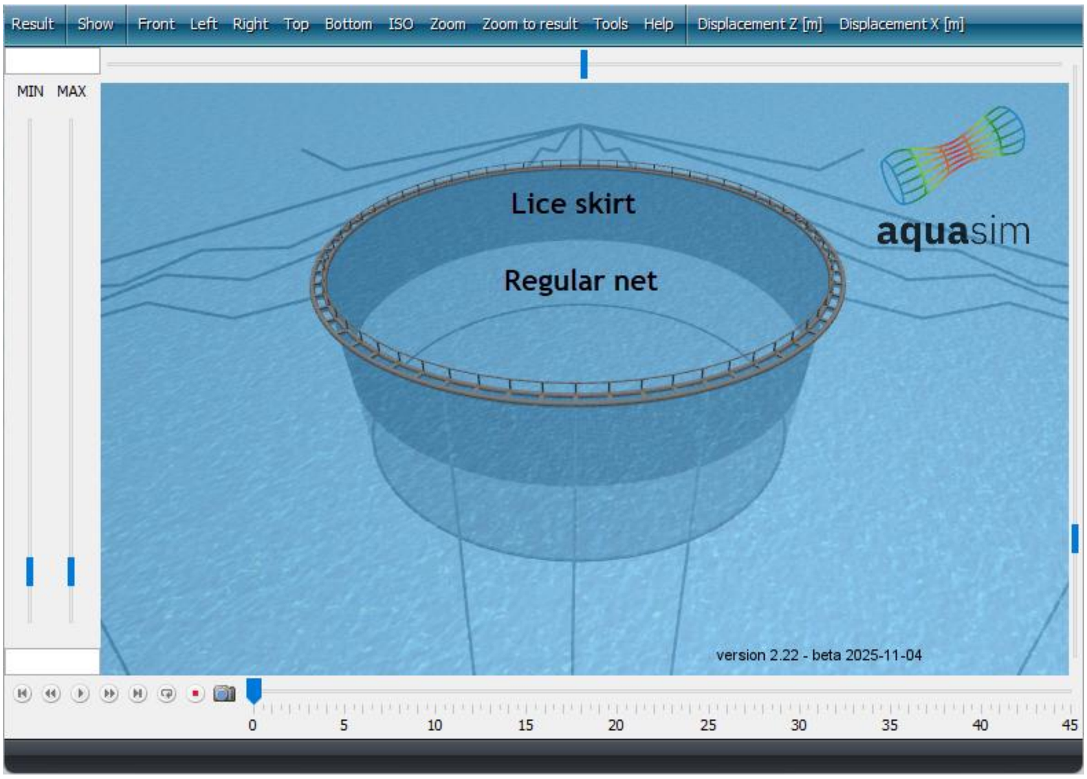

Figure 14

When you apply *Lice skirt* in your model, some additional results are available in AquaView. They are found under **Result** > **Impermeable net**. Here you can view different forces that is relevant for impermeable nets. Select **Result** > **Impermeable net** > **Relative pressure [mH2O]**. This is the hydrodynamic pressure difference that acts around the skirt due to waves and current. Meaning the pressure on the outside surface minus the pressure on the inside surface. This option can therefore indicate how strongly the lice skirt is being pushed by fluid flow.

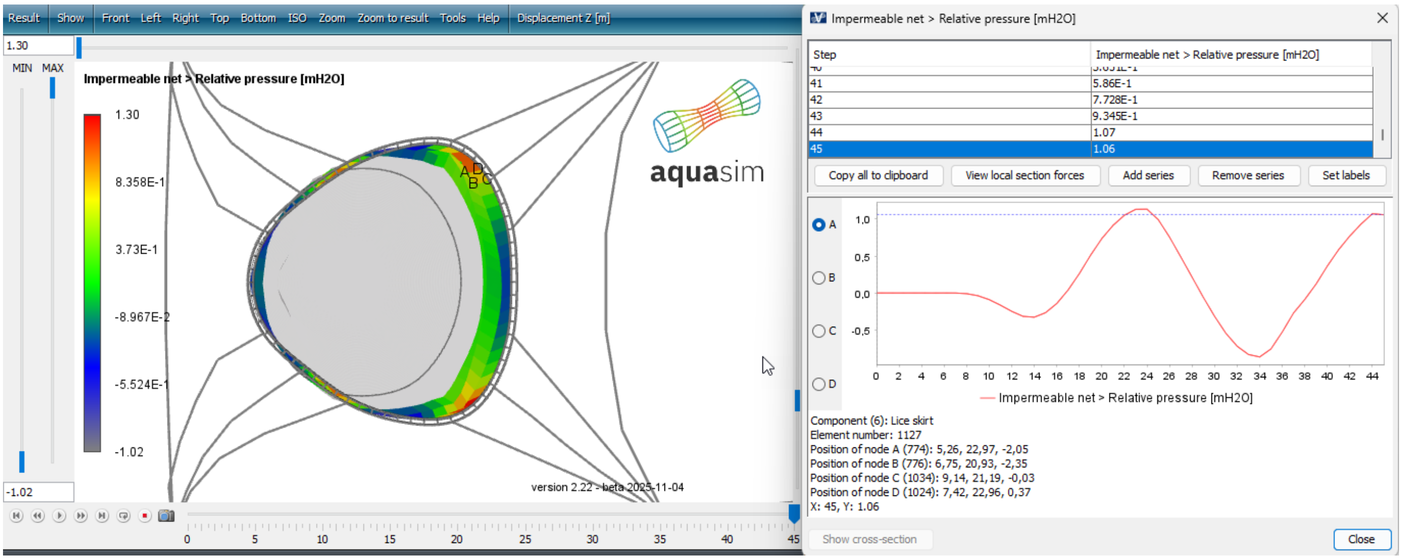

Figure 15

From the results, it is observed on the upstream side a region of high negative pressure (blue region). But further down in the water column, the pressure increases (green region). The blue region may be due to stagnation of the flow, then it starts to accelerate and try du “escape” underneath the skirt leading the fluid to be accelerated.

The largest relative pressure is seen on the sides, in the region where the bridles are attached. This is where the flow accelerations are highest. On the downstream side the flow separates and forms a wake. In this region negative (suction) pressure is created.

6.9 Comparison models with and without lice skirt

One interesting point is to investigate the effect the lice skirt has on response of the aquaculture cage and force distribution in the anchor lines. In this section we shall present and illustrate the effect lice skirt has.

Load the AquaSim model *Net.amodel*. This model is identical to *LiceSkirt.amodel*, only that the load formulation of the lice skirt is changed from *Lice skirt* to *Regular net*. This will result in a conventional net that is permeable.

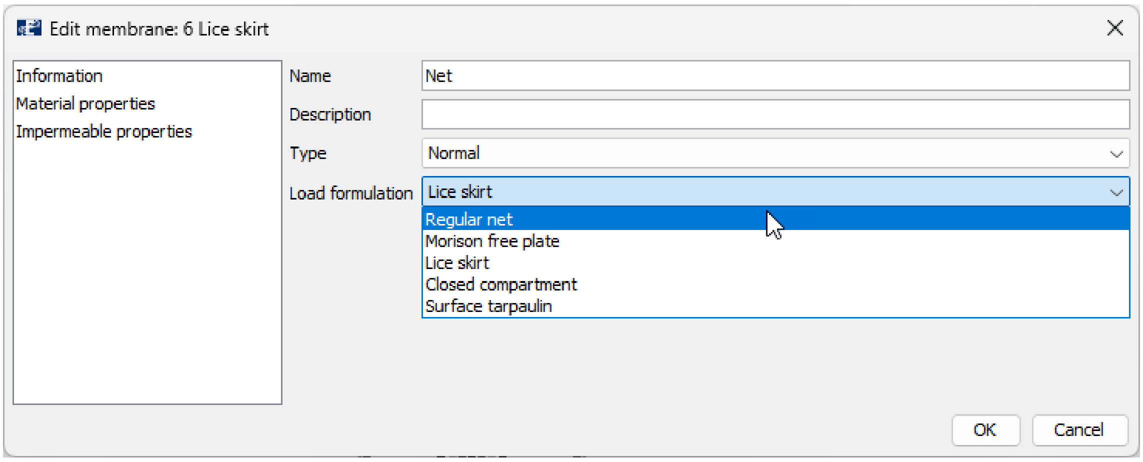

Figure 16

Select **Export** and the tab **Normal**. If you compare the two models, you may see that the load conditions are identical. With a wave amplitude of 1.4 meters, period 4 seconds and current along x-axis 0.5m/s.

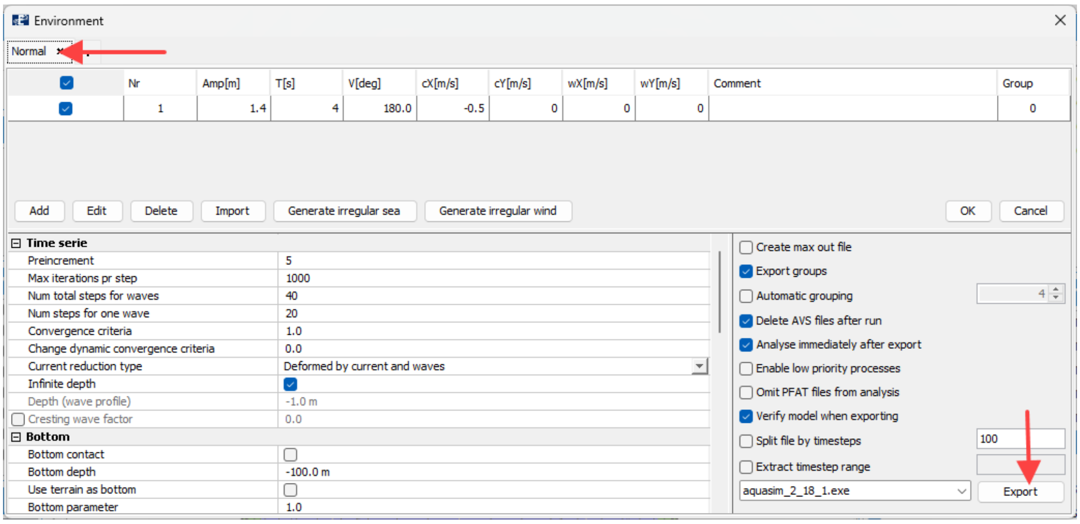

Figure 17

Export the model and **run an analysis**. We named the analysis *net_*, and will result in an avz-file that is named *net_01.avz*. When the analysis is finished, open this file.

You may have the *liceskirt_01.avz* and *net_01.avz* open parallel to compare more easily.

6.9.1 Response and deformations

The two models are presented side-by-side in the figure below.

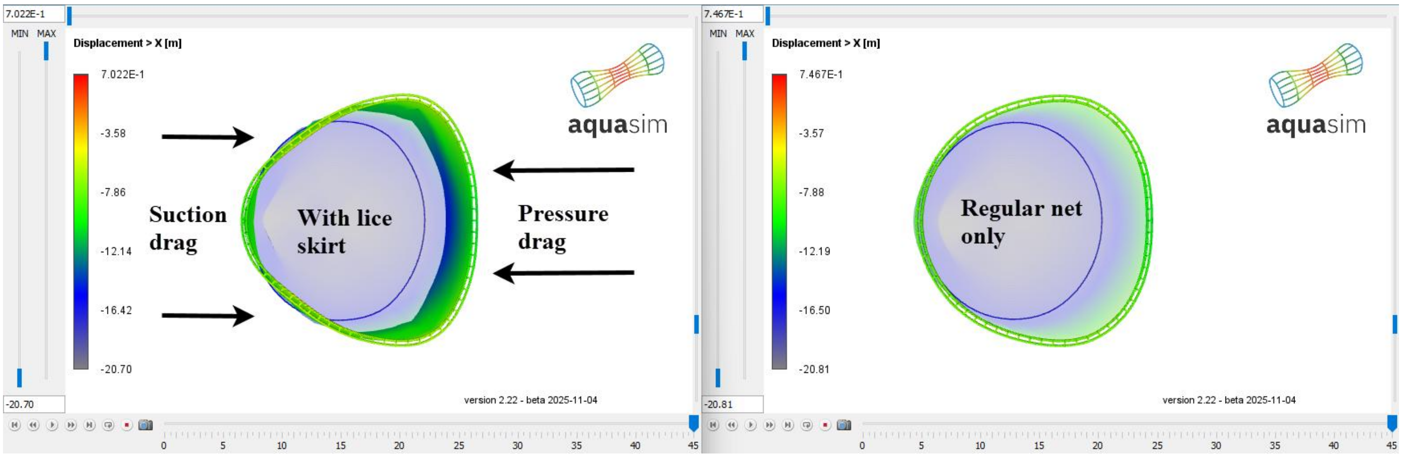

Figure 18

You can see that introducing a lice skirt significantly changes the response of the cage. With a regular net (to right in the figure above), the flow is almost free to pass through the net. This results in moderate deformations of the cage; it remains close to circular.

When the lice skirt is introduced (to left in the figure above), it acts as a solid barrier. The effect of pressure drag upstream, and suction drag downstream, result in much larger deformations. The deformations are also asymmetric compared to when only having a permeable net.

You may also see that the response of the floating collar is somewhat slower and more rigid in the case with the lice skirt. This is due to the trapped water inside the lice skirt – but also the water on the outside – that must be accelerated in order for the floating collar to displace.

6.9.2 Forces in the floating collar and anchor system

Comparing von Mises stress in the floating collar, one can clearly see in the figure below that the introduction of a lice skirt has increased the load on this construction part.

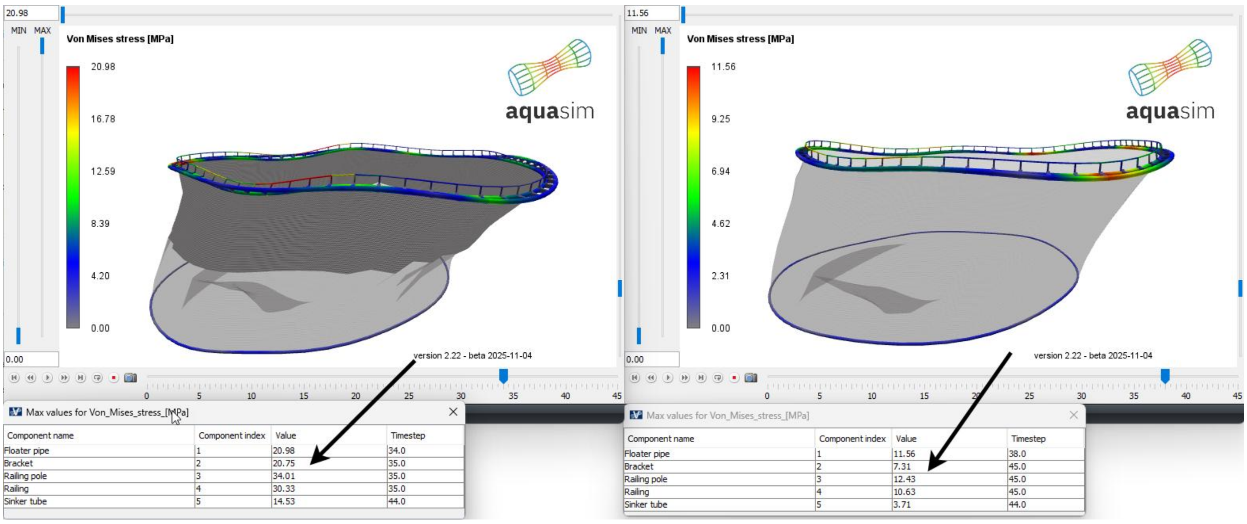

Figure 19

7 Trouble-shooting

As with all types of FEM modelling and analyses, one may encounter some challenges in terms of convergence issues and subsequent poor reliability in the analysis results. The cause of the convergence issues may be countless – it may span from improper discretization, human errors such as incorrect material data, lack of damping in your model, too much damping in your model and so on.

There is unfortunately no quick fix, or one fix for all problems that you may encounter when working with dynamic analysis. In the following sections, some suggestions to improve the quality of convergence in your model is presented. These suggestions assume that you have control over the material data for your lice skirt (and other components in your model as well).

When trouble-shooting, the user is encouraged to simplify the problem and the model in order to reduce possible sources of errors. Then conduct one change at a time, to keep track of the effect of the introduced changes.

7.1 Discretization of lice skirt panels

Building FEM-models one will always encounter the trade-off between the level of details, number of elements and access to computer power. The more comprehensive the model is, the more time and effort is needed to solve the differential equations.

In some situations, too few membrane panels representing the lice skirt may cause the model to be too stiff, especially in the water line where waves contribute to large response. The user may then introduce additional elements on the lice skirt in the vicinity of the water line. This is illustrated in the figure below.

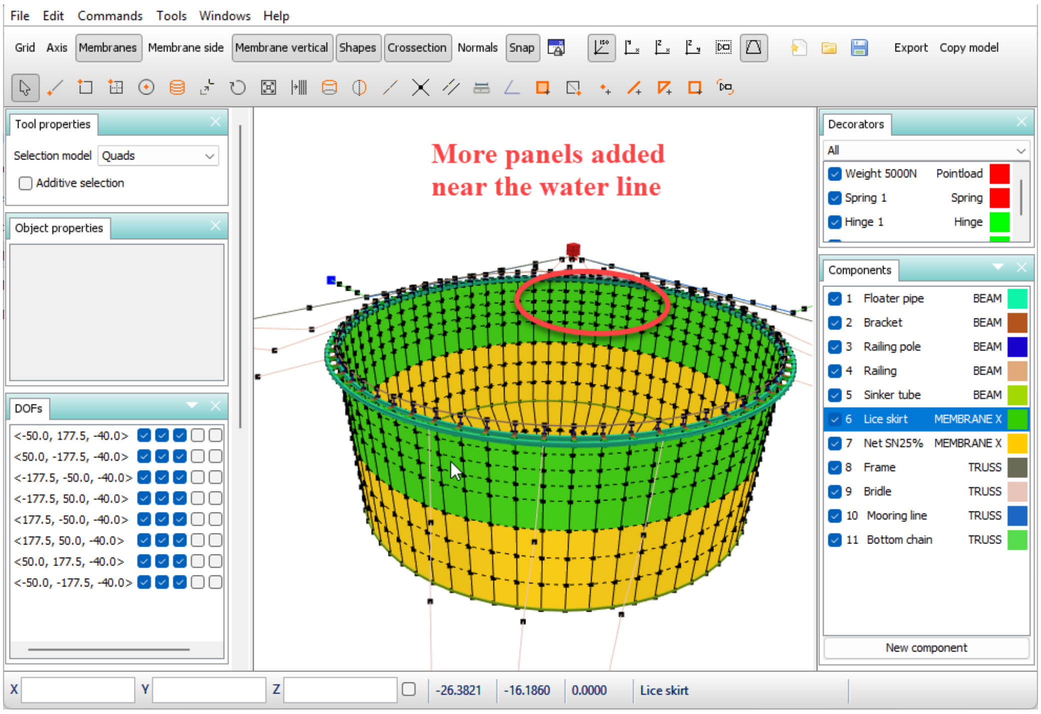

Figure 20

Bear in mind, the convergence issue might as well be due to too many elements in the lice skirt. Making it too soft may introduce unrealistic large response. The user is encouraged to try either to increase or decrease the number of elements in the vicinity of the water line.

7.2 Discretization of time-domain analysis

The discretization of the time-domain analysis is governed by **Num total steps for waves** and **Num steps for one wave**.

Time serie	
Preincrement	5
Max iterations pr step	1000
Num total steps for waves	100
Num steps for one wave	50
Convergence criteria	1.0
Change dynamic convergence criteria	0.0

Figure 21

For hydrodynamic problems that encounter large deformations over short period of time, it can help to increase the number of steps. This better enables AquaSim to capture differences in forces and displacements between iterations.

However, this will only have a limited effect. You will come to a point where increasing the number of steps does not have any effect – you will also have the trade-off that increased number of steps will affect the computational time of your analysis.

7.3 Convergence criteria

The **Convergence criteria** (and **Change dynamic convergence criteria**) simply explained, is the tolerance that regulates when AquaSim should be satisfied with one analysis-step and move to the next. The larger this value, the larger difference in forces and displacements are allowed between each iteration in an analysis-step.

Having this too strict or too spacious, this can make it difficult to achieve convergence in the analyses. The user may try to tighten the convergence criteria – or vice versa – to see if this improves convergence.

Time serie	
Preincrement	5
Max iterations pr step	1000
Num total steps for waves	100
Num steps for one wave	50
Convergence criteria	0.1
Change dynamic convergence criteria	0.0

Figure 22

7.4 Load model

For highly deformable structures like lice skirts, the load model Flexible tarp can sometimes struggle to converge due to large local deformations near the free surface. Applying the hybrid load model Hybrid flexible tarp/ Numerical diffraction may reduce these issues because it separates the load calculations into two parts. The *Numerical diffraction* part provides a more stable, linearized wave excitation force, independent of deformation of the lice skirt. The *Flexible tarp* part provides non-linear drag forces and deformation-dependent loads that are important to achieve realistic response.

The user can, as a suggestion, try the hybrid model with a weight factor of 0.25, as seen in the figure below. Meaning that the Flexible tarp model is weighted 75% and the *Numerical diffraction* is weighted 25%.

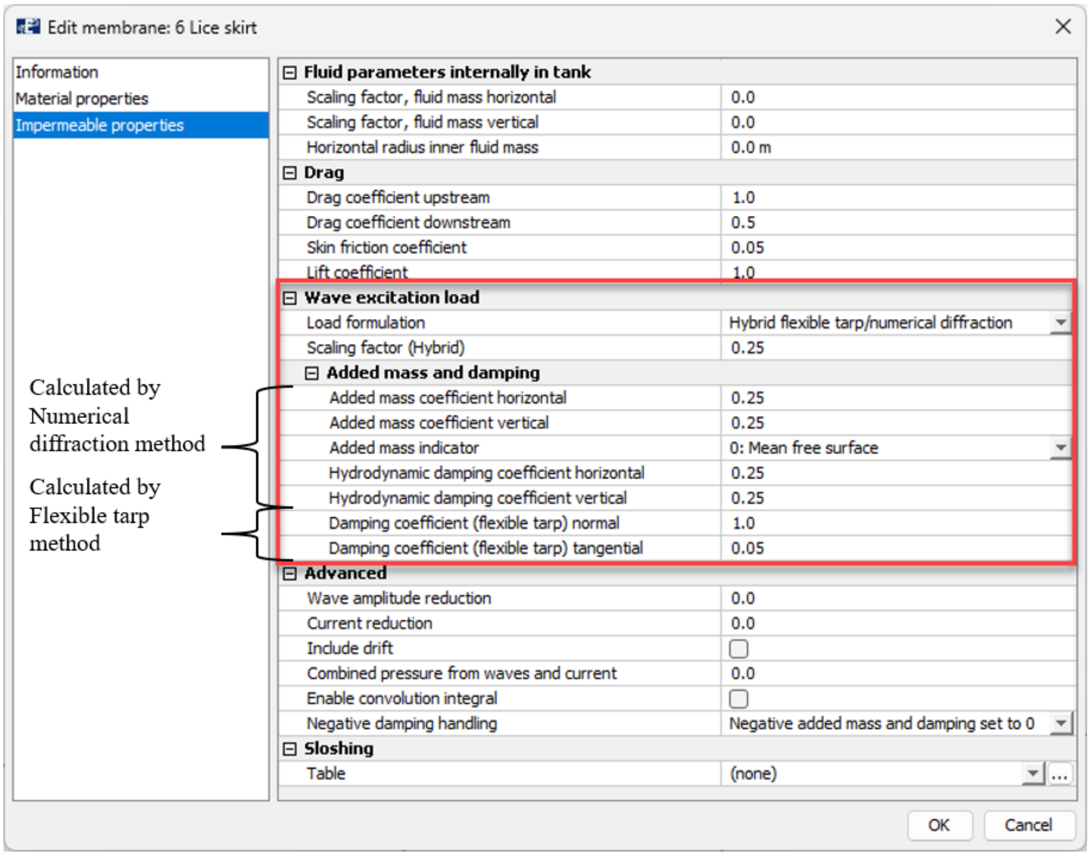

Figure 23

Numerical diffraction calculates hydrodynamic forces applying the open-source NEMOH algorithm. It is based on linear potential flow theory and solves the hydrodynamic boundary value problem by distributing sink and sources on the panel. The Added mass coefficient and Hydrodynamic damping coefficients then acts as scaling factors the added mass and damping found by NEMOH.

8 Summary

In this tutorial you have been presented in detail the different parameters that determines the loads on lice skirts, comparison of loads with and without lice skirts, and at last some trouble-shooting suggestions for your model.

The user must have in mind that dealing with hydrodynamical problems in FEM software can be a challenging task due to large deformations and complex load transfers between components. There are no one-fix for all issues that may arise. When trouble-shooting, the user is encouraged to simplify the problem and the model in order to reduce possible sources of errors. Then conduct one change at a time, in order to keep track of the effect of the introduced changes.

Remember, if you want more in-depth information about lice skirt parameters and other impermeable structures check out these references (Aquastructures, 2025b) (Aquastructures, 2025a).

9 References

Aquastructures. (2025a). *Loads on impermeable nets and large volume objects in AquaSim.* TR-FOU-2328-5-Rev 10.

Aquastructures. (2025b). *Lice skirt and Closed compartment - Impermeable properties in AquaSim.* TN-FOU-100004-7.

Aquastructures. (2025c, TR-20000-583-1). *AquaEdit User Manual*.

10 Revision comments

Revision no.	Comment
1.0	First publication
2.0	Revised to be compatible with AquaSim 2.22.0

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