Created in COMSOL Multiphysics 5.6

Corrosion Protection of Multiple Oil Platforms

Introduction

This example extends the corrosion protection system analysis of the Corrosion Protection of an Oil Platform Using Sacrificial Anodes example. In that example it was seen that the bottom parts of the legs of the platform structure were the parts of the cathode least protected from corrosion. We would now like to investigate what would be the effect on these potentials in a larger structure complex, in this case consisting of an array of oil platforms.

These geometries typically tend to render large problems sizes, and for performance and memory reasons we therefore choose to approximate all electrodes of the model as cylinders of a given radius along the edges of a wireframe geometry, shown in Figure 1 for a single platform, by using the Current Distribution, Boundary Elements interface.

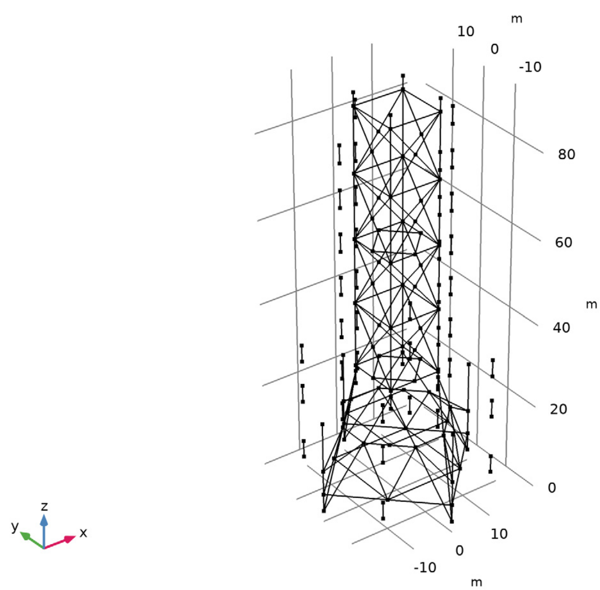

Figure 1: Single platform wireframe geometry.

Model Definition

The physics settings of this problem are the same as for the Corrosion Protection of an Oil Platform Using Sacrificial Anodes example. The conceptual difference in how the model is set up is that all radii, used by the Boundary Elements (BEM) formulation, need to be specified in the physics interface, and that a symmetry plane is placed at the sea bottom.

Note that the BEM formulation extends to infinity and this implies that the insulating effect of the sea surface is not included in the model, but since this example focuses on the lower part of the legs, the impact of this on the analysis is deemed small.

Results and Discussion

Figure 2 shows the potential distribution when only one platform is simulated. The results are similar to the Corrosion Protection of an Oil Platform Using Sacrificial Anodes example, which was using a full 3D geometry and a standard FEM formulation.

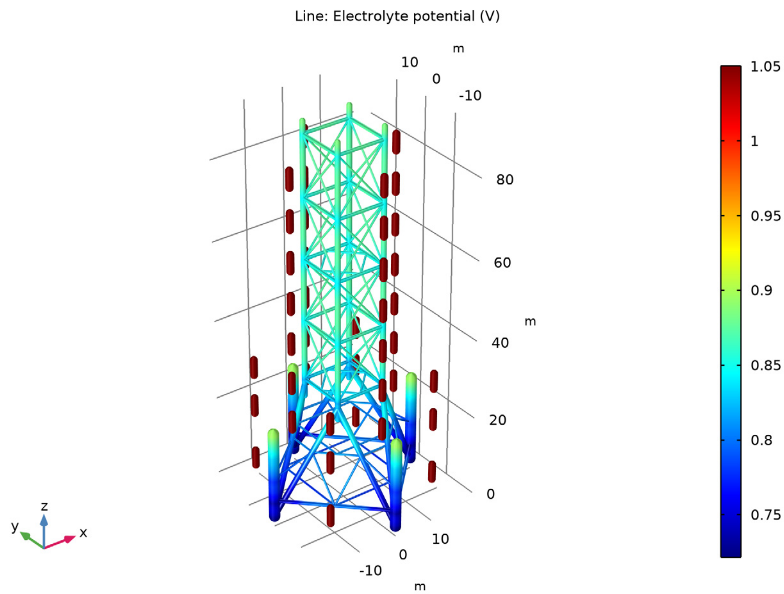

Figure 2: Potential distribution for a single platform.

Figure 3 shows the electrolyte potential distribution on an array of four platforms, including the sacrificial anodes. Figure 4 shows the steel potential on the cathodes vs an

Ag/AgCl reference for the same data. The potential at the bottom of the inner legs is shifted 40 mV, indicating a worse protection on these parts.

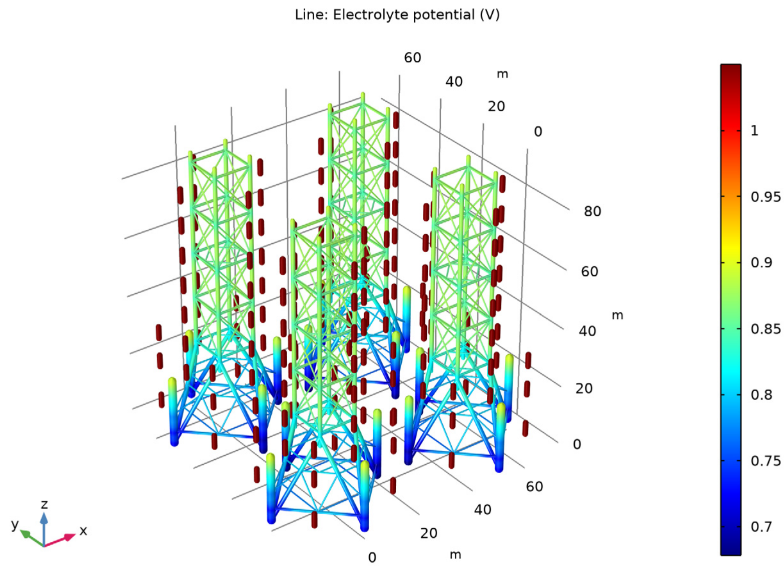

Figure 3: Potential distribution for multiple platforms.

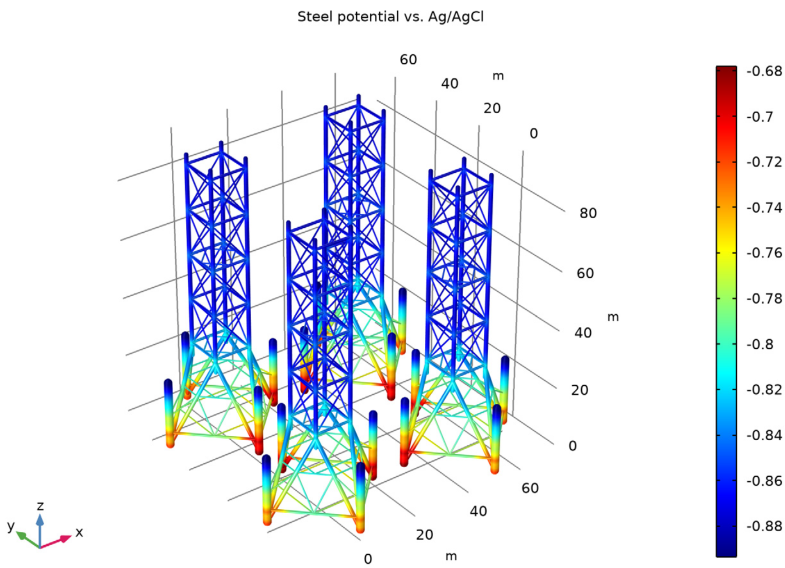

Figure 4: Potential distribution on the steel structure vs an Ag/AgCl reference electrode.

Application Library path: `Corrosion_Module/Cathodic_Protection/multiple_oil_platforms`

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click **Model Wizard**.

MODEL WIZARD

1 In the **Model Wizard** window, click **3D**.

2 In the **Select Physics** tree, select **Electrochemistry> Primary and Secondary Current Distribution>Current Distribution, Boundary Elements (cdbem)**.

3 Click **Add**.

4 Click **Study**.

5 In the **Select Study** tree, select **General Studies>Stationary**.

6 Click **Done**.

GEOMETRY 1

Start by loading the wireframe geometry of a single oil platform from a file. You will model the problem on a single platform first, and then extend the geometry by the use of an array at a later step.

Import 1 (imp1)

1 In the **Home** toolbar, click **Import**.

2 In the **Settings** window for **Import**, locate the **Import** section.

3 Click **Browse**.

4 Browse to the model's Application Libraries folder and double-click the file `oil_platform_wireframe.mphbin`.

5 Click **Import**.

Your imported geometry should now look like Figure 1.

DEFINITIONS

The next step is to create a number of geometry edge selections. Start with the anodes and cathodes.

Anodes

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Edge**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type `10-22, 123-129, 154-160, 225-237` in the **Selection** text field.

(You can either type in the edge numbers in the dialog window, or copy and paste them from the model documentation file.)

6 Click **OK**.

7 In the **Settings** window for **Explicit**, type `Anodes` in the **Label** text field.

Cathodes

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Edge**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type `1-9,23-122, 130-153, 161-224, 238-240` in the **Selection** text field.

6 Click **OK**.

7 In the **Settings** window for **Explicit**, type `Cathodes` in the **Label** text field.

The following selections will be used to assign different radii to different parts of the wireframe geometry.

Beams 1

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Edge**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type `1, 4, 7, 117, 119, 121, 161, 163, 165, 238-240` in the **Selection** text field.

6 Click **OK**.

7 In the **Settings** window for **Explicit**, type `Beams 1` in the **Label** text field.

Beams 2

1 In the **Definitions** toolbar, click **Explicit**.

2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.

3 From the **Geometric entity level** list, choose **Edge**.

4 Click **Paste Selection**.

5 In the **Paste Selection** dialog box, type `2-3, 26, 29, 42-45, 50, 57, 64, 71, 90-93, 96, 100, 104, 108, 111, 114, 118, 162, 167, 170, 173-176, 179, 183, 187, 191, 204-211, 221, 223` in the **Selection** text field.

6 Click **OK**.

7 In the **Settings** window for **Explicit**, type `Beams 2` in the **Label** text field.

Beams 3

1 In the **Definitions** toolbar, click **Explicit**.
2 In the **Settings** window for **Explicit**, locate the **Input Entities** section.
3 From the **Geometric entity level** list, choose **Edge**.
4 Click **Paste Selection**.
5 In the **Paste Selection** dialog box, type `5-6, 32, 35, 46, 48, 53, 56, 59, 62, 67, 70, 73, 75-76, 83, 94, 99, 102, 107, 110, 120, 130, 136, 143, 149, 164, 177, 182, 185, 190, 193-194, 199, 217, 219` in the **Selection** text field.
6 Click **OK**.
7 In the **Settings** window for **Explicit**, type `Beams 3` in the **Label** text field.

Beams 4

1 In the **Definitions** toolbar, click **Difference**.
2 In the **Settings** window for **Difference**, locate the **Geometric Entity Level** section.
3 From the **Level** list, choose **Edge**.
4 Locate the **Input Entities** section. Under **Selections to add**, click **Add**.
5 In the **Add** dialog box, select **Cathodes** in the **Selections to add** list.
6 Click **OK**.
7 In the **Settings** window for **Difference**, locate the **Input Entities** section.
8 Under **Selections to subtract**, click **Add**.
9 In the **Add** dialog box, in the **Selections to subtract** list, choose **Beams 1**, **Beams 2**, and **Beams 3**.
10 Click **OK**.
11 In the **Settings** window for **Difference**, type `Beams 4` in the **Label** text field.

CURRENT DISTRIBUTION, BOUNDARY ELEMENTS (CDBEM)

In this model we are interested in analyzing the potential close to the sea bottom. Enable a symmetry in xy-plane at $z = 0$ and then set up the actual physics. That is: the electrolyte conductivity, the electrolyte potential condition on the anodes and the current density condition on the cathode. Note that multiple current density nodes are used to set different radii to beams of the platform.

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Current Distribution, Boundary Elements (cdbem)**.

2 In the **Settings** window for **Current Distribution, Boundary Elements**, click to expand the **Symmetry** section.

3 From the **Symmetry in the xy plane** list, choose **Symmetric**.

Electrolyte 1

1 In the **Model Builder** window, under **Component 1 (comp1)>Current Distribution, Boundary Elements (cdbem)** click **Electrolyte 1**.

2 In the **Settings** window for **Electrolyte**, locate the **Electrolyte** section.

3 In the σ_l text field, type `5[S/m]`.

Electrolyte Potential 1

1 In the **Physics** toolbar, click **Edges** and choose **Electrolyte Potential**.

2 In the **Settings** window for **Electrolyte Potential**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **Anodes**.

4 Locate the **Edge Radius** section. In the **Edge radius** text field, type `0.86[m]`.

5 Locate the **Electrolyte Potential** section. In the $\phi_{l,bnd}$ text field, type `1.05[V]`.

Electrolyte Current Density 1

1 In the **Physics** toolbar, click **Edges** and choose **Electrolyte Current Density**.

2 In the **Settings** window for **Electrolyte Current Density**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **Beams 1**.

4 Locate the **Edge Radius** section. In the **Edge radius** text field, type `1.26[m]`.

5 Locate the **Electrolyte Current Density** section. In the $i_{n,l}$ text field, type `-0.1[A/m^2]`.

Electrolyte Current Density 2

1 In the **Physics** toolbar, click **Edges** and choose **Electrolyte Current Density**.

2 In the **Settings** window for **Electrolyte Current Density**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **Beams 2**.

4 Locate the **Edge Radius** section. In the **Edge radius** text field, type `0.64[m]`.

5 Locate the **Electrolyte Current Density** section. In the $i_{n,l}$ text field, type `-0.1[A/m^2]`.

Electrolyte Current Density 3

1 In the **Physics** toolbar, click **Edges** and choose **Electrolyte Current Density**.

2 In the **Settings** window for **Electrolyte Current Density**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **Beams 3**.

4 Locate the **Edge Radius** section. In the **Edge radius** text field, type `0.43[m]`.

5 Locate the **Electrolyte Current Density** section. In the $i_{n,1}$ text field, type `-0.1[A/m^2]`.

Electrolyte Current Density 4

1 In the **Physics** toolbar, click **Edges** and choose **Electrolyte Current Density**.

2 In the **Settings** window for **Electrolyte Current Density**, locate the **Edge Selection** section.

3 From the **Selection** list, choose **Beams 4**.

4 Locate the **Edge Radius** section. In the **Edge radius** text field, type `0.229[m]`.

5 Locate the **Electrolyte Current Density** section. In the $i_{n,1}$ text field, type `-0.1[A/m^2]`.

STUDY 1

The model is now ready to be solved. This model uses the default mesh and solver settings. Clear the Generate default plots check box and manually plot electrolyte potential and normal electrolyte current density.

1 In the **Model Builder** window, click **Study 1**.

2 In the **Settings** window for **Study**, locate the **Study Settings** section.

3 Clear the **Generate default plots** check box.

4 In the **Home** toolbar, click **Compute**.

RESULTS

Electrolyte Potential

1 In the **Home** toolbar, click **Add Plot Group** and choose **3D Plot Group**.

2 In the **Settings** window for **3D Plot Group**, type `Electrolyte Potential` in the **Label** text field.

Line 1

1 In the **Electrolyte Potential** toolbar, click **Line**.

2 In the **Settings** window for **Line**, locate the **Coloring and Style** section.

3 From the **Line type** list, choose **Tube**.

4 In the **Tube radius expression** text field, type `cdbem.redge`.

5 Select the **Radius scale factor** check box.

6 In the **Electrolyte Potential** toolbar, click **Plot**.

Normal Electrolyte Current Density

1 In the **Model Builder** window, right-click **Electrolyte Potential** and choose **Duplicate**.

2 In the **Settings** window for **3D Plot Group**, type `Normal Electrolyte Current Density` in the **Label** text field.

Line 1

1 In the **Model Builder** window, expand the **Normal Electrolyte Current Density** node, then click **Line 1**.

2 In the **Settings** window for **Line**, locate the **Expression** section.

3 In the **Expression** text field, type `cdbem.nIl`.

4 In the **Normal Electrolyte Current Density** toolbar, click **Plot**.

STUDY 1

Solver Configurations

Make a copy of the solution for future reference.

Solution 1 (sol1)

1 In the **Model Builder** window, expand the **Study 1>Solver Configurations** node.

2 Right-click **Solution 1 (sol1)** and choose **Solution>Copy**.

Solution 1 - Single Platform

1 In the **Model Builder** window, under **Study 1>Solver Configurations** click **Solution 1 - Copy 1 (sol2)**.

2 In the **Settings** window for **Solution**, type `Solution 1 - Single Platform` in the **Label** text field.

Solution 2 - Multiple Platforms

1 In the **Model Builder** window, under **Study 1>Solver Configurations** click **Solution 1 (sol1)**.

2 In the **Settings** window for **Solution**, type `Solution 2 - Multiple Platforms` in the **Label** text field.

GEOMETRY 1

Modify the geometry by adding an array and resolve the problem.

Array 1 (arr1)

1 In the **Geometry** toolbar, click **Transforms** and choose **Array**.

2 Select the object **imp1** only.

3 In the **Settings** window for **Array**, locate the **Size** section.

4 In the **y size** text field, type `2`.

5 In the **x size** text field, type `2`.

6 Locate the **Displacement** section. In the **x** text field, type `50[m]`.

7 In the **y** text field, type `50[m]`.

8 Click **Build All Objects**.

STUDY 1

COMSOL will automatically assign the proper physics settings in the new geometry by associating the settings on the new geometry entities to the ones for the single platform. The problem is therefore ready to be solved.

1 In the **Home** toolbar, click **Compute**.

RESULTS

Electrolyte Potential

1 In the **Electrolyte Potential** toolbar, click **Plot**.

2 Click the **Zoom Extents** button in the **Graphics** toolbar.

Steel potential vs. Ag/AgCl

1 Right-click **Electrolyte Potential** and choose **Duplicate**.

2 In the **Settings** window for **3D Plot Group**, type `Steel potential vs. Ag/AgCl` in the **Label** text field.

3 Locate the **Plot Settings** section. Clear the **Plot dataset edges** check box.

4 Click to expand the **Title** section. From the **Title type** list, choose **Label**.

Line 1

1 In the **Model Builder** window, expand the **Steel potential vs. Ag/AgCl** node, then click **Line 1**.

2 In the **Settings** window for **Line**, locate the **Expression** section.

3 In the **Expression** text field, type `-phil`.

Selection 1

1 Right-click **Line 1** and choose **Selection**.

2 In the **Settings** window for **Selection**, locate the **Selection** section.

3 From the **Selection** list, choose **Cathodes**.

4 In the **Steel potential vs. Ag/AgCl** toolbar, click **Plot**.

5 Click the **Zoom Extents** button in the **Graphics** toolbar.