

# 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

I In the Model Wizard window, click 间 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 I

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 I (imp1)

- I 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

- I In the **Definitions** toolbar, click **here 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

- I In the **Definitions** toolbar, click **here 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 I

- I In the **Definitions** toolbar, click **here 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

- I In the **Definitions** toolbar, click **here 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

- I In the **Definitions** toolbar, click **here 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

- I 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.
- IO Click OK.
- II 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.

I In the Model Builder window, under Component I (compl) 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

- In the Model Builder window, under Component I (compl)>Current Distribution, Boundary Elements (cdbem) click Electrolyte I.
- 2 In the Settings window for Electrolyte, locate the Electrolyte section.
- **3** In the  $\sigma_l$  text field, type 5[S/m].

#### Electrolyte Potential I

- I 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  $\phi_{1,\text{bnd}}$  text field, type 1.05[V].

## Electrolyte Current Density I

- I 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 I.
- 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  $i_{n,1}$  text field, type -0.1[A/m<sup>2</sup>].

#### Electrolyte Current Density 2

- I 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  $i_{n,1}$  text field, type -0.1[A/m<sup>2</sup>].

#### Electrolyte Current Density 3

- I 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<sup>2</sup>].

## Electrolyte Current Density 4

- I 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<sup>2</sup>].

#### STUDY I

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.

- I In the Model Builder window, click Study I.
- 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

- I 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 I

- I 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

- I 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 I

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

# STUDY I

#### Solver Configurations

Make a copy of the solution for future reference.

Solution 1 (soll)

- I In the Model Builder window, expand the Study I>Solver Configurations node.
- 2 Right-click Solution I (soll) and choose Solution>Copy.

#### Solution 1 - Single Platform

- In the Model Builder window, under Study I>Solver Configurations click Solution I -Copy I (sol2).
- 2 In the Settings window for Solution, type Solution 1 Single Platform in the Label text field.

Solution 2 - Multiple Platforms

- I In the Model Builder window, under Study I>Solver Configurations click Solution I (soll).
- 2 In the Settings window for Solution, type Solution 2 Multiple Platforms in the Label text field.

## GEOMETRY I

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

#### Array I (arr I)

- I In the Geometry toolbar, click 💭 Transforms and choose Array.
- 2 Select the object impl 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 I

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.

I In the **Home** toolbar, click **= Compute**.

# RESULTS

**Electrolyte Potential** 

- I In the Electrolyte Potential toolbar, click 🗿 Plot.
- **2** Click the  $4 \rightarrow$  **Zoom Extents** button in the **Graphics** toolbar.

Steel potential vs. Ag/AgCl

- I 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 I

- I In the Model Builder window, expand the Steel potential vs. Ag/AgCl node, then click Line I.
- 2 In the Settings window for Line, locate the Expression section.
- 3 In the Expression text field, type -phil.

Selection 1

- I Right-click Line I 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 **Graphics** toolbar.