Created in COMSOL Multiphysics 6.2

Hydrogen Diffusion in Metals

Introduction

Hydrogen embrittlement refers to the degradation of metal ductility due to the absorption of hydrogen. The metal becomes more brittle and thus cracks might initiate at lower stress levels. It is important to estimate hydrogen concentration and the speed at which it diffuses into the metal in order to predict and avoid crack formation and propagation.

This model shows how to simulate the uptake and diffusion of hydrogen in a notched metal sample from an aqueous electrolyte. It uses the Transport in Solids interface to model both the concentration-driven and stress-driven diffusion in a solid.

Model Definition

The model geometry consists of a metal part with an initial defect as depicted in Figure 1.

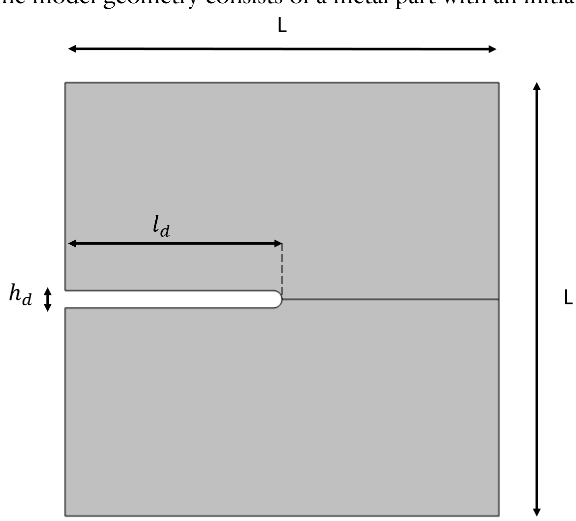

Figure 1: Model geometry.

The part size is L = 20 mm, and the defect is h_{d} = 0.4 mm wide and extends for l_{d} = 10 mm into the specimen.

The electrolyte is located on the left side of the metal part and a hydrogen influx is assigned on the boundary where the solid is in contact with it. The initial defect is also filled with electrolyte.

The solid is constrained on the bottom and right edges with a roller boundary condition. A prescribed displacement of 0.05 mm is applied on the top boundary to produce a state of stress and study its effect on hydrogen diffusion. Although not considered in this example, the symmetry about the *xz*-plane through the defect could be exploited to reduce the computational size.

The hydrogen diffusion is studied using the mass balance equation

$$\frac{\partial c}{\partial t} = -\nabla \cdot \Gamma + G$$

where c is the concentration (SI unit: $\mathrm{mol/m^3}$), Γ is the molar flux, and G is a source term. Following Ref. 1, hydrogen can be present both in the interstitial metal lattice and in traps,

$$c = c_\mathrm{l} + \sum_i c_{\mathrm{t},\,i}$$

To study the diffusion of the hydrogen in the interstitial lattice, the mass balance equation is rewritten as follows,

$$\frac{\partial c_\mathrm{l}}{\partial t} = -\nabla \cdot \Gamma + G - \left(\frac{\partial c_{\mathrm{t,1}}}{\partial t} + \frac{\partial c_{\mathrm{t,2}}}{\partial t}\right)$$

where only two trap types are considered. A relation between the trap and lattice concentration can be found assuming a low lattice occupancy, see Ref. 1 for details.

Both the concentration gradient (Fick's law) and the stress gradient drive the diffusion of hydrogen in the metal,

$$\Gamma = -D\nabla c_\mathrm{l} + \frac{D c_\mathrm{l} \Omega_\mathrm{H}}{RT}\nabla \sigma_\mathrm{h}$$

where D is the lattice diffusion coefficient, Ω_H is the partial molar volume of hydrogen, and $\sigma_\mathrm{h} = \frac{1}{3}\mathrm{tr}(\sigma)$ is the hydrostatic stress. The electrolyte and the chemical reactions therein are not modeled explicitly; instead an approximation for the flux as a function of the pH and the electrolyte potential, V_e, is used (Ref. 1),

$$\begin{aligned} j = -\Gamma \cdot \mathbf{N} = \quad & (1-\theta)(k_\mathrm{va} c_\mathrm{H} \exp(-\alpha_\mathrm{va}\eta) + k_\mathrm{vb}\exp(-\alpha_\mathrm{vb}\eta)) \\ & -\theta(k_\mathrm{ha} c_\mathrm{H} \exp(-\alpha_\mathrm{ha}\eta) + k_\mathrm{hb}\exp(-\alpha_\mathrm{hb}\eta) + 2k_\mathrm{T}\theta) \end{aligned}$$

where

$$\eta = \frac{(V_\mathrm{m} - V_\mathrm{eq} - V_\mathrm{e})F}{RT},$$

$$\theta = \frac{c_1}{\frac{k_a}{k_{ar}}(N - c_1) + c_1},$$

and

$$c_H = 10^{-pH + 3}$$

The electrolyte parameters used in the influx expression are inspired from Ref. 1 and reported in Table 1.

TABLE 1: MODEL PARAMETERS.

Parameter	**Value**
Diffusion coefficient (D)	2E-9 m^2/s
Metal potential (V_m)	-0.5 V
Equilibrium potential (V_{eq})	0 V
Electrolyte potential (V_e)	-0.025 V
Hydrogen partial molar volume (Ω_H)	2E-6 m^3/mol
Temperature (T)	293.15 K
Volmer forward reaction coefficient, acid (α_{va})	0.48
Volmer forward reaction coefficient, basic (α_{vb})	0.48
Heyrovsky forward reaction coefficient, acid (α_{ha})	0.33
Heyrovsky forward reaction coefficient, basic (α_{hb})	0.33
Volmer forward reaction rate, acid (k_{va})	1E-4 m/s
Volmer forward reaction rate, basic (k_{vb})	1E-8 mol/m^2s
Heyrovsky forward reaction rate, acid (k_{ha})	1E-10 m/s
Heyrovsky forward reaction rate, basic (k_{hb})	9E-10 mol/m^2s
Tafel forward reaction rate (k_T)	1E-6 mol/m^2s
Absorption forward reaction rate (k_a)	1E5 m/s
Absorption backward reaction rate (k_{ar})	9E9 m/s
Lattice sites concentration (N)	1e6 mol/m^3
Trap 1 concentration (n_{t1})	2 mol/m^3
Trap 2 concentration (n_{t2})	1 mol/m^3
pH	13

Results and Discussion

Figure 2 shows the concentration and the flux direction of the hydrogen after 2 hours. The concentration is higher at the sharp corner of the crack because of the greater area exposed to the electrolyte.

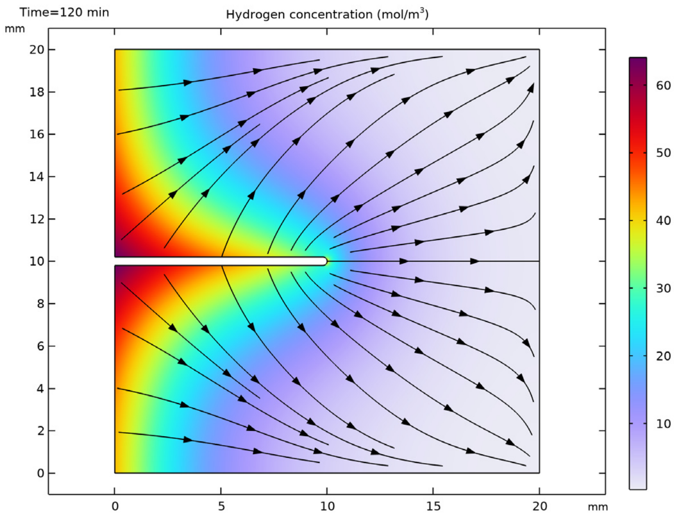

Figure 2: Hydrogen concentration and hydrogen flux after 2 hours.

Figure 3 shows the flux direction for the concentration-driven (red) and stress-driven (black) contribution to the total flux.

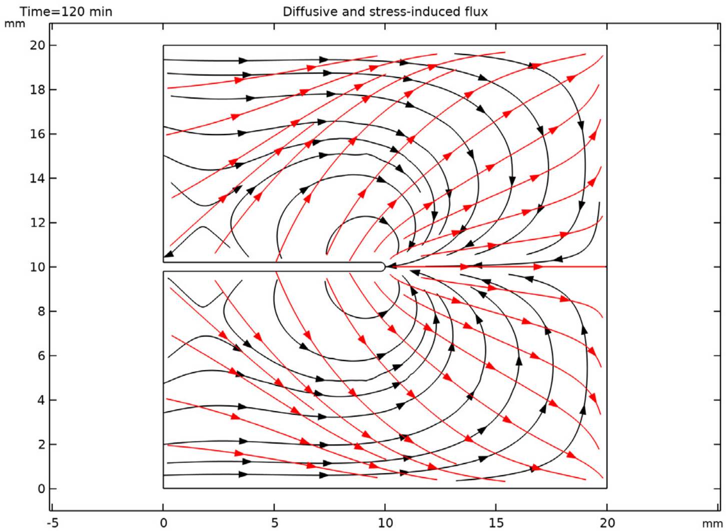

Figure 3: Streamline plot of the concentration-driven (red) and stress-driven (black) hydrogen flux.

The effect of the stress on hydrogen absorption can be seen in Figure 4. The figure compares the time evolution of the hydrogen concentration at the tip of the defect with and without the stress contribution to the flux. The stress-induced flux increases the absorption of hydrogen.

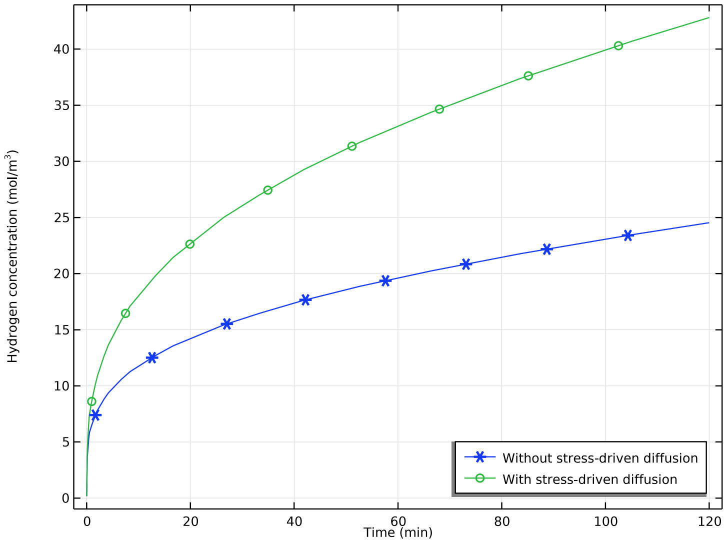

Figure 4: Hydrogen concentration with and without stress contribution to the diffusion flux at the tip of the defect.

The hydrogen concentration in the metal part along the centerline is shown in Figure 5 for both cases.

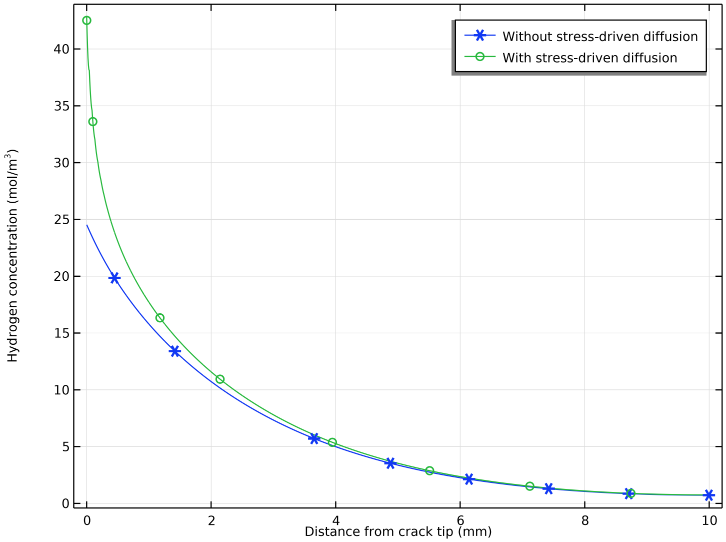

Figure 5: Hydrogen diffusion depth along the centerline of the specimen.

Figure 6 below shows the hydrostatic stress and the deformed geometry. There is a stress concentration at the crack tip, which enhances the hydrogen adsorption

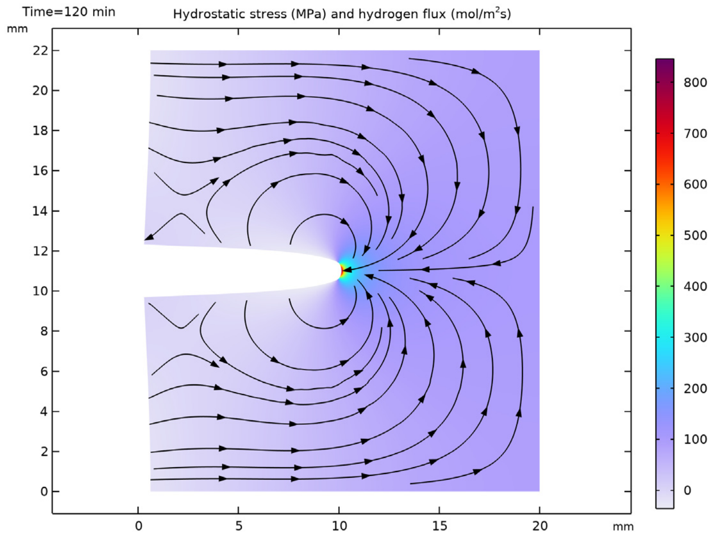

Figure 6: Hydrostatic stress and hydrogen flux in the deformed configuration (100 times amplified).

Notes About the COMSOL Implementation

The stress-driven diffusion can be included through the **External Flux** subfeature. A parametric study is used to evaluate the solution with and without the additional flux due to the hydrostatic stress gradient.

Reference

1. T. Hageman and E. Martinez-Paneda, *An electro-chemo-mechanical framework for predicting hydrogen uptake in metals due to aqueous electrolytes*, Corrosion Science, vol. 208, 110681, 2022

Application Library path: `Structural_Mechanics_Module/Diffusion_in_Solids/hydrogen_diffusion`

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 **2D**.

2 In the **Select Physics** tree, select **Structural Mechanics>Solid Mechanics (solid)**.

3 Click **Add**.

4 In the **Select Physics** tree, select **Chemical Species Transport>Transport in Solids (ts)**.

5 Click **Add**.

6 Click **Study**.

7 In the **Select Study** tree, select **General Studies>Time Dependent**.

8 Click **Done**.

GLOBAL DEFINITIONS

Geometric Parameters

1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.

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

3 In the table, enter the following settings:

Name	Expression	Value	Description
L	`20[mm]`	0.02 m	`Domain size`
Ld	`10[mm]`	0.01 m	`Defect length`
Hd	`0.4[mm]`	4E-4 m	`Defect height`

4 In the **Label** text field, type `Geometric Parameters`.

Model Parameters

1 In the **Home** toolbar, click **Parameters** and choose **Add>Parameters**.

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

3 Click **Load from File**.

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

5 In the **Label** text field, type `Model Parameters`.

GEOMETRY 1

1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry 1**.

2 In the **Settings** window for **Geometry**, locate the **Units** section.

3 From the **Length unit** list, choose **mm**.

Metal Domain

1 In the **Geometry** toolbar, click **Square**.

2 In the **Settings** window for **Square**, locate the **Size** section.

3 In the **Side length** text field, type `L`.

4 Click to expand the **Layers** section. In the table, enter the following settings:

Layer name	Thickness (mm)
`Layer 1`	`L/2`

5 In the **Label** text field, type `Metal Domain`.

Fracture

1 In the **Geometry** toolbar, click **Rectangle**.

2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.

3 In the **Width** text field, type `Ld`.

4 In the **Height** text field, type `Hd`.

5 Locate the **Position** section. In the **y** text field, type `(L-Hd)/2`.

6 In the **Label** text field, type `Fracture`.

Fracture Fillet

1 In the **Geometry** toolbar, click **Fillet**.

2 On the object **r1**, select Points 2 and 3 only.

3 In the **Settings** window for **Fillet**, locate the **Radius** section.

4 In the **Radius** text field, type `Hd/2`.

5 In the **Label** text field, type `Fracture Fillet`.

Remove Fracture

1 In the **Geometry** toolbar, click **Booleans and Partitions** and choose **Difference**.

2 Select the object **sq1** only.

3 In the **Settings** window for **Difference**, locate the **Difference** section.

4 Click to select the **Activate Selection** toggle button for **Objects to subtract**.

5 Select the object **fil** only.

6 In the **Label** text field, type `Remove Fracture`.

7 Click **Build All Objects**.

ADD MATERIAL

1 In the **Home** toolbar, click **Add Material** to open the **Add Material** window.

2 Go to the **Add Material** window.

3 In the tree, select **Built-in>Iron**.

4 Click **Add to Component** in the window toolbar.

5 In the **Home** toolbar, click **Add Material** to close the **Add Material** window.

SOLID MECHANICS (SOLID)

Prescribed Displacement: Top

1 In the **Model Builder** window, under **Component 1 (comp1)** right-click **Solid Mechanics (solid)** and choose **Prescribed Displacement**.

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

3 Select Boundary 6 only.

4 In the **Settings** window for **Prescribed Displacement**, locate the **Prescribed Displacement** section.

5 From the **Displacement in y direction** list, choose **Prescribed**.

6 In the u_{0y} text field, type `U0`.

7 In the **Label** text field, type `Prescribed Displacement: Top`.

Roller 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Roller**.

2 Select Boundaries 2, 8, and 9 only.

DEFINITIONS

Define an **Analytic** function for the trap contribution, see Ref. 1 for details.

Trap Contribution

1 In the **Home** toolbar, click f(X) **Functions** and choose **Local>Analytic**.

2 In the **Settings** window for **Analytic**, locate the **Definition** section.

3 In the **Expression** text field, type `(NT/N)*exp(Eb/(R_const*T0))/((1+(max(cl,0)/N)*exp(Eb/(R_const*T0)))^2)`.

4 In the **Arguments** text field, type `cl, NT, Eb`.

5 Locate the **Units** section. In the **Function** text field, type `1`.

6 In the table, enter the following settings:

Argument	Unit
cl	mol/m^3
NT	mol/m^3
Eb	kJ/mol

7 In the **Function name** text field, type `trapFun`.

8 In the **Label** text field, type `Trap Contribution`.

Variables 1

1 In the **Model Builder** window, right-click **Definitions** and choose **Variables**.

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

3 Click **Load from File**.

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

Influx Boundary Selection

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 **Boundary**.

4 Select Boundaries 1, 3–5, 10, and 11 only.

5 In the **Label** text field, type `Influx Boundary Selection`.

TRANSPORT IN SOLIDS (TS)

Add the stress gradient contribution as an external flux in the material frame. Multiply the flux definition with the parameter `para` to be able to activate and deactivate the stress-driven flux in a parametric study.

Solid 1

1 In the **Model Builder** window, under **Component 1 (comp1)>Transport in Solids (ts)** click **Solid 1**.

2 In the **Settings** window for **Solid**, locate the **Diffusion** section.

3 In the D_c text field, type `D`.

External Flux 1

1 In the **Physics** toolbar, click **Attributes** and choose **External Flux**.

2 In the **Settings** window for **External Flux**, locate the **External Flux** section.

3 Select the **Species c** check box.

4 Click to expand the **Advanced** section. From the **Frame** list, choose **Reference configuration**.

5 Locate the **External Flux** section. In the $\Gamma_{ext,c}$ table, enter the following settings:

`D_sigma*d(-solid.pm,X)*para`
`D_sigma*d(-solid.pm,Y)*para`

Source: Hydrogen Traps

1 In the **Physics** toolbar, click **Domains** and choose **Source**.

2 Click in the **Graphics** window and then press Ctrl+A to select both domains.

3 In the **Settings** window for **Source**, locate the **Sources** section.

4 In the S_c text field, type `-srcCoeff*cTIME`.

5 In the **Label** text field, type `Source: Hydrogen Traps`.

Flux 1

1 In the **Physics** toolbar, click **Boundaries** and choose **Flux**.

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

3 From the **Selection** list, choose **Influx Boundary Selection**.

4 Locate the **Inward Flux** section. In the $\gamma_{0,c}$ text field, type `J_influx`.

MESH 1

Due to symmetry, you can mesh half the geometry and use the **Copy Domain** node to copy the mesh to the other half.

Free Quad 1

1 In the **Mesh** toolbar, click **Free Quad**.

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

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

4 Select Domain 2 only.

Distribution 1

1 Right-click **Free Quad 1** and choose **Distribution**.

2 Select Boundary 5 only.

3 In the **Settings** window for **Distribution**, locate the **Distribution** section.

4 From the **Distribution type** list, choose **Predefined**.

5 In the **Number of elements** text field, type 40.

6 In the **Element ratio** text field, type 2.

Distribution 2

1 In the **Model Builder** window, right-click **Free Quad 1** and choose **Distribution**.

2 Select Boundary 7 only.

3 In the **Settings** window for **Distribution**, locate the **Distribution** section.

4 From the **Distribution type** list, choose **Predefined**.

5 In the **Number of elements** text field, type 60.

6 In the **Element ratio** text field, type 10.

7 From the **Growth rate** list, choose **Exponential**.

Size

1 In the **Model Builder** window, under **Component 1 (comp1)>Mesh 1** click **Size**.

2 In the **Settings** window for **Size**, locate the **Element Size** section.

3 From the **Predefined** list, choose **Extra fine**.

Copy Domain 1

1 In the **Model Builder** window, right-click **Mesh 1** and choose **Copying Operations>Copy Domain**.

2 Select Domain 2 only.

3 In the **Settings** window for **Copy Domain**, locate the **Destination Domains** section.

4 Click to select the **Activate Selection** toggle button.

5 Select Domain 1 only.

6 Click **Build All**.

STUDY 1

Step 1: Time Dependent

1 In the **Model Builder** window, under **Study 1** click **Step 1: Time Dependent**.

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

3 From the **Time unit** list, choose **min**.

4 In the **Output times** text field, type `0 10^{range(log10(1/60),1/10,log10(120))} 120`.

Parametric Sweep

Add a **Parametric Sweep** to activate and deactivate the stress-driven flux contribution.

1 In the **Study** toolbar, click **Parametric Sweep**.

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

3 Click **Add**.

4 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
para (Activation parameter)	0 1	

5 In the **Study** toolbar, click **Compute**.

RESULTS

Hydrostatic Stress

1 In the **Settings** window for **2D Plot Group**, type `Hydrostatic Stress` in the **Label** text field.

2 Click to expand the **Title** section. From the **Title type** list, choose **Manual**.

3 In the **Title** text area, type `Hydrostatic stress (MPa) and hydrogen flux (mol/m<sup>2</sup>s)`.

4 In the **Parameter indicator** text field, type `Time=eval(t,min) min`.

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

Surface 1

1 In the **Model Builder** window, expand the **Hydrostatic Stress** node, then click **Surface 1**.

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

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

4 From the **Unit** list, choose **MPa**.

Deformation

1 In the **Model Builder** window, expand the **Surface 1** node, then click **Deformation**.

2 In the **Settings** window for **Deformation**, locate the **Scale** section.

3 Select the **Scale factor** check box. In the associated text field, type `100`.

Streamline 1

1. In the **Model Builder** window, right-click **Hydrostatic Stress** and choose **Streamline**.
2. In the **Settings** window for **Streamline**, locate the **Expression** section.
3. In the **X-component** text field, type ts.extflux_cx.
4. In the **Y-component** text field, type ts.extflux_cy.
5. In the **Hydrostatic Stress** toolbar, click **Plot**.
6. Locate the **Streamline Positioning** section. From the **Positioning** list, choose **Uniform density**.
7. Locate the **Coloring and Style** section. Find the **Point style** subsection. From the **Type** list, choose **Arrow**.
8. Click to expand the **Inherit Style** section. From the **Plot** list, choose **Surface 1**.

Deformation 1

1. Right-click **Streamline 1** and choose **Deformation**.
2. In the **Hydrostatic Stress** toolbar, click **Plot**.

Concentration

1. In the **Model Builder** window, under **Results** click **Transported Quantity (ts)**.
2. In the **Settings** window for **2D Plot Group**, locate the **Title** section.
3. From the **Title type** list, choose **Manual**.
4. In the **Title** text area, type Hydrogen concentration (mol/m³).
5. In the **Parameter indicator** text field, type Time=eval(t,min) min.
6. In the **Label** text field, type Concentration.

Surface 1

1. In the **Model Builder** window, expand the **Concentration** node, then click **Surface 1**.
2. In the **Settings** window for **Surface**, locate the **Coloring and Style** section.
3. Click **Change Color Table**.
4. In the **Color Table** dialog box, select **Rainbow>Prism** in the tree.
5. Click **OK**.

Streamline 1

1. In the **Model Builder** window, click **Streamline 1**.
2. In the **Settings** window for **Streamline**, locate the **Coloring and Style** section.
3. Find the **Point style** subsection. From the **Color** list, choose **Black**.
4. From the **Arrow length** list, choose **Normalized**.

5 Locate the **Inherit Style** section. From the **Plot** list, choose **Surface 1**.

6 In the **Concentration** toolbar, click **Plot**.

Diffusive and Stress-Induced Flux

Add a plot to visualize the concentration-driven and stress-driven hydrogen flux.

1 In the **Home** toolbar, click **Add Plot Group** and choose **2D Plot Group**.

2 In the **Settings** window for **2D Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 1/Parametric Solutions 1 (sol2)**.

4 Locate the **Title** section. From the **Title type** list, choose **Manual**.

5 In the **Title** text area, type `Diffusive and stress-induced flux`.

6 In the **Parameter indicator** text field, type `Time=eval(t,min) min`.

7 In the **Label** text field, type `Diffusive and Stress-Induced Flux`.

Streamline 1

1 Right-click **Diffusive and Stress-Induced Flux** and choose **Streamline**.

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

3 In the **X-component** text field, type `ts.extflux_cx`.

4 In the **Y-component** text field, type `ts.extflux_cy`.

5 Locate the **Streamline Positioning** section. From the **Positioning** list, choose **Uniform density**.

6 Locate the **Coloring and Style** section. Find the **Point style** subsection. From the **Type** list, choose **Arrow**.

7 Right-click **Streamline 1** and choose **Duplicate**.

Streamline 2

1 In the **Model Builder** window, click **Streamline 2**.

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

3 In the **X-component** text field, type `ts.dflux_cx`.

4 In the **Y-component** text field, type `ts.dflux_cy`.

5 Locate the **Coloring and Style** section. Find the **Point style** subsection. From the **Color** list, choose **Red**.

6 In the **Diffusive and Stress-Induced Flux** toolbar, click **Plot**.

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

Hydrogen Concentration in Metal

Add a plot to visualize the hydrogen concentration along the centerline of the solid with and without considering stress-driven diffusion.

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

2 In the **Settings** window for **1D Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 1/Parametric Solutions 1 (sol2)**.

4 From the **Time selection** list, choose **Last**.

5 Click to expand the **Title** section. From the **Title type** list, choose **None**.

6 Locate the **Plot Settings** section.

7 Select the **x-axis label** check box. In the associated text field, type `Distance from crack tip (mm)`.

8 Select the **y-axis label** check box. In the associated text field, type `Hydrogen concentration (mol/m<sup>3</sup>)`.

9 In the **Label** text field, type `Hydrogen Concentration in Metal`.

Line Graph 1

1 Right-click **Hydrogen Concentration in Metal** and choose **Line Graph**.

2 Select Boundary 7 only.

3 In the **Settings** window for **Line Graph**, locate the **y-Axis Data** section.

4 In the **Expression** text field, type `c`.

5 Click to expand the **Legends** section. Select the **Show legends** check box.

6 From the **Legends** list, choose **Manual**.

7 In the table, enter the following settings:

Legends
`Without stress-driven diffusion`
`With stress-driven diffusion`

8 Click to expand the **Coloring and Style** section. Find the **Line markers** subsection. From the **Marker** list, choose **Cycle**.

9 From the **Positioning** list, choose **Interpolated**.

10 In the **Hydrogen Concentration in Metal** toolbar, click **Plot**.

Hydrogen Concentration at Crack Tip

Add a plot to visualize the hydrogen concentration at the crack tip as a function of time.

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

2 In the **Settings** window for **1D Plot Group**, locate the **Data** section.

3 From the **Dataset** list, choose **Study 1/Parametric Solutions 1 (sol2)**.

4 Locate the **Title** section. From the **Title type** list, choose **None**.

5 Locate the **Plot Settings** section.

6 Select the **y-axis label** check box. In the associated text field, type `Hydrogen concentration (mol/m<sup>3</sup>)`.

7 In the **Label** text field, type `Hydrogen Concentration at Crack Tip`.

8 Locate the **Legend** section. From the **Position** list, choose **Lower right**.

Point Graph 1

1 Right-click **Hydrogen Concentration at Crack Tip** and choose **Point Graph**.

2 Select Point 7 only.

3 In the **Settings** window for **Point Graph**, locate the **y-Axis Data** section.

4 In the **Expression** text field, type `c`.

5 Locate the **x-Axis Data** section. From the **Unit** list, choose **min**.

6 Click to expand the **Coloring and Style** section. Find the **Line markers** subsection. From the **Marker** list, choose **Cycle**.

7 From the **Positioning** list, choose **Interpolated**.

8 Click to expand the **Legends** section. Select the **Show legends** check box.

9 From the **Legends** list, choose **Manual**.

10 In the table, enter the following settings:

Legends
`Without stress-driven diffusion`
`With stress-driven diffusion`

11 In the **Hydrogen Concentration at Crack Tip** toolbar, click **Plot**.