COMSOL MULTIPHYSICS®

Micromixer

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COMSOL

Micromixer

Introduction

This example studies a laminar static mixer with two parallel sets of split-reshape-recombine mixing elements. Figure 1 shows the geometry of a single mixing element.

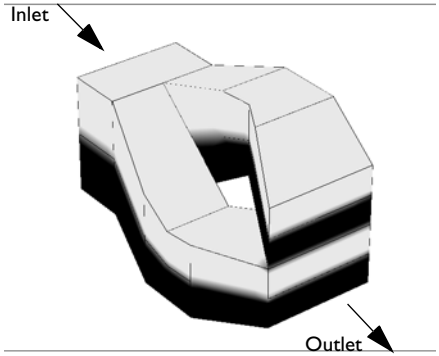

Figure 1: The micromixer splits the incoming fluid in the direction perpendicular to the interface separating the two fluid layers. After recombining them, the mixer stacks the two flows on top of each other, resulting in four fluid layers.

Each mixing element doubles the number of fluid layers, resulting in a fast mixing process. This technique is suited for laminar flow mixing and has small pressure losses. In this model, the mixing structure consists of two parallel sets of mixing elements, where each set is two elements long. You measure the mixing quality with the relative variance of the concentration profile, S, calculated as

$$S = \frac{s_x}{s_{\text{inlet}}}$$

$$s_x = \int_{K_x} (c - \bar{c})^2 dA$$

where K_x is the yz-plane intersecting the mixing structure at coordinate x, and c is the mean concentration.

DOMAIN EQUATIONS

The fluid flow is described by the Navier-Stokes equations

$$\rho\frac{\partial \mathbf{u}}{\partial t} - \nabla \cdot \eta(\nabla \mathbf{u} + (\nabla \mathbf{u})^T) + \rho \mathbf{u} \cdot \nabla \mathbf{u} + \nabla p = 0$$

$$\nabla \cdot \mathbf{u} = 0$$

where ρ denotes the density (kg/m^3), $\mathbf{u}$ the velocity (m/s), η denotes the viscosity (N·s/m^2), and p represents the pressure (Pa). The modeled fluid is water with a viscosity of $1 \cdot 10^{-3}$ N·s/m^2 and a density of 1000 kg/m^3.

The mass flux is given by diffusion and convection, and the resulting mass balance is

$$\nabla \cdot (-D\nabla c + c\mathbf{u}) = 0$$

where D denotes the diffusion coefficient (m^2/s) and c gives the concentration (mol/m^3). The modeled species is bicarbonate ions with a diffusion coefficient of $1.49 \cdot 10^{-9}$ m^2/s.

BOUNDARY CONDITIONS

At the inlet the model assumes fully developed laminar flow. It sets the velocity to a parabolic profile with a mean velocity of 0.01 m/s. At the outlet, the model sets the pressure to zero. All other boundaries have a no-slip condition

$$\mathbf{u} = 0,$$

The inlet concentration has a discontinuous profile where the upper half has a concentration of 27 mol/m^3 and the lower half is pure water. The boundary condition is defined such that

$$c|_{\text{inlet}} = \begin{cases} c_0 & z > 0 \\ 0 & z \le 0. \end{cases}$$

Results

Figure 2 shows the final concentration profile. The concentration values in some points of the solution are slightly negative; this is due to the numerical method.

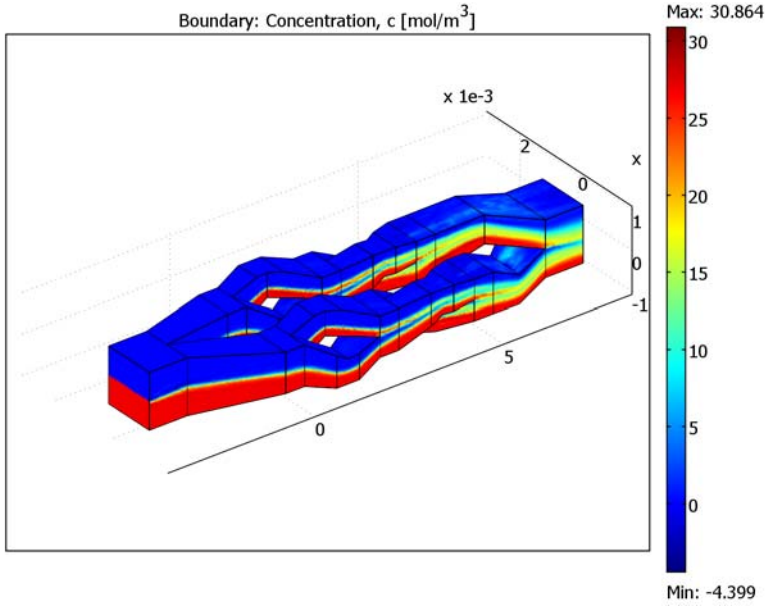

Figure 2: Following three split-reshape-recombine cycles, the outflow has eight fluid layers.

Using boundary integration to calculate the relative variance of the concentration at the inlet and outlet, this setup reaches a mixing quality of 0.31 (for perfect mixing this value would be 0, and a value of 1 means no mixing at all). To improve this quality, add mixing elements.