The Bürger-Diehl model: The right integrator for the right model

Garneau C.[1], Diehl S.[2], Torfs E.[3], Bürger R.[4], Claeys F.A.[5], Nopens I.[3], Vanrolleghem P.A.[1*]

[1] modelEAU, Département de génie civil et de génie des eaux, Université Laval, 1060 Avenue de la Médecine, Québec, Qc, G1V 0A6, Canada
[2] Centre for Mathematical Sciences, Lund University, Sweden
[3] CI2MA and Departamento de Ingeniería Matemática, Facultad de Ciencias Físicas y Matemáticas, Universidad de Concepción, Chile
[4] BIOMATH, Department of Mathematical Modelling, Statistics and Bioinformatics, Ghent University, Belgium
[5] DHI, Guldensporenpark 104 block K, B-9820 Merelbeke, Belgium
* peter.vanrolleghem@gci.ulaval.ca

Introduction

The Bürger-Diehl settling model is a physically-sound spatially discretized settling model. We show that its complexity does not prevent acceptable computation times at various spatial discretization

Objectives

- Compare the results obtained with the Bürger-Diehl model under different spatial discretization
- Propose optimal solver settings to solve the model

Influence of the spatial discretization

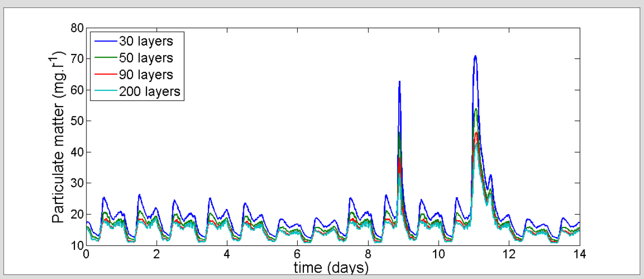


Figure 1: Concentration of particulate matter exiting the secondary clarifier with respect to the spatial discretization of the Bürger-Diehl model. As the number of layer increases, the simulation converges to a stable solution.

Steady state simulations

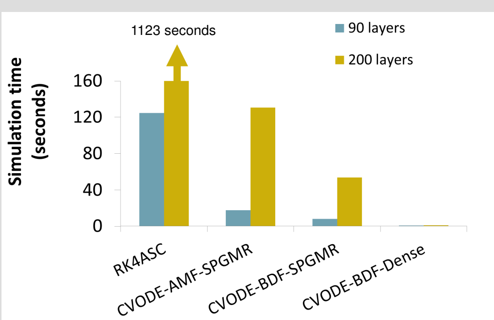
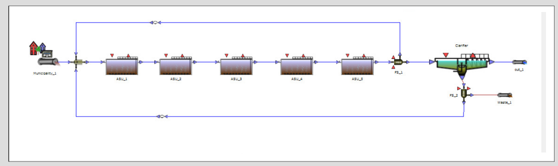


Figure 2: Simulation time to reach steady state. Using exact Newton methods provided impressive acceleration of the computation with the CVODE-BDF-Dense algorithm.

Methodology

- The Bürger-Diehl model was applied to the **Benchmark Simulation Model 1**. Two simulations were performed:
  - 100 days with constant inputs to steady state
  - 14 days of dynamic inputs with two storm events



- Four spatial discretization were tested in the secondary settler: 30, 50, 90 and 200 layers
- Four solver configurations were compared:
  - Runge-Kutta 4 with adaptive time step (**RK4ASC**)
  - CVODE from the SUNDIALS library using Adams-Moulton formula and an internal iterative solver (SPGMR) iterative solver (**CVODE-AMF-SPGMR**).
  - CVODE using the Backward Differential Formulas and the SOGMR iterative solver (**CVODE-BDF-SPGMR**).
  - CVODE using the Backward Differential Formulas and the Newton-Raphson solver operating on dense matrices (**CVODE-BDF-Dense**).

Dynamic simulations

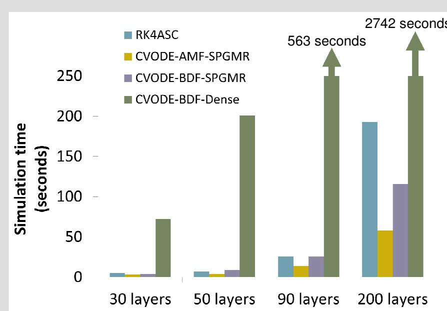


Figure 3: Simulation time with dynamic inputs. The CVODE-AMF-SPGMR provided the overall optimal computation time. The CVODE-BDF-Dense was always the worst solver under dynamics.

Key findings

- The spatial discretization has an important effect on accuracy and simulation time.
- The steady state simulation was fastest when using the CVODE-BDF-Dense solver.
- Dynamic simulation was fastest with the stiff solver CVODE-AM-SPGMR.

UNIVERSITÉ LAVAL

http://modelEAU.fsg.ulaval.ca
cyrilgarneau@gmail.com