National Centre of Scientific Research "DEMOKRITOS"

Detection & Simulation of Mineral Precipitation in Geothermal Installations

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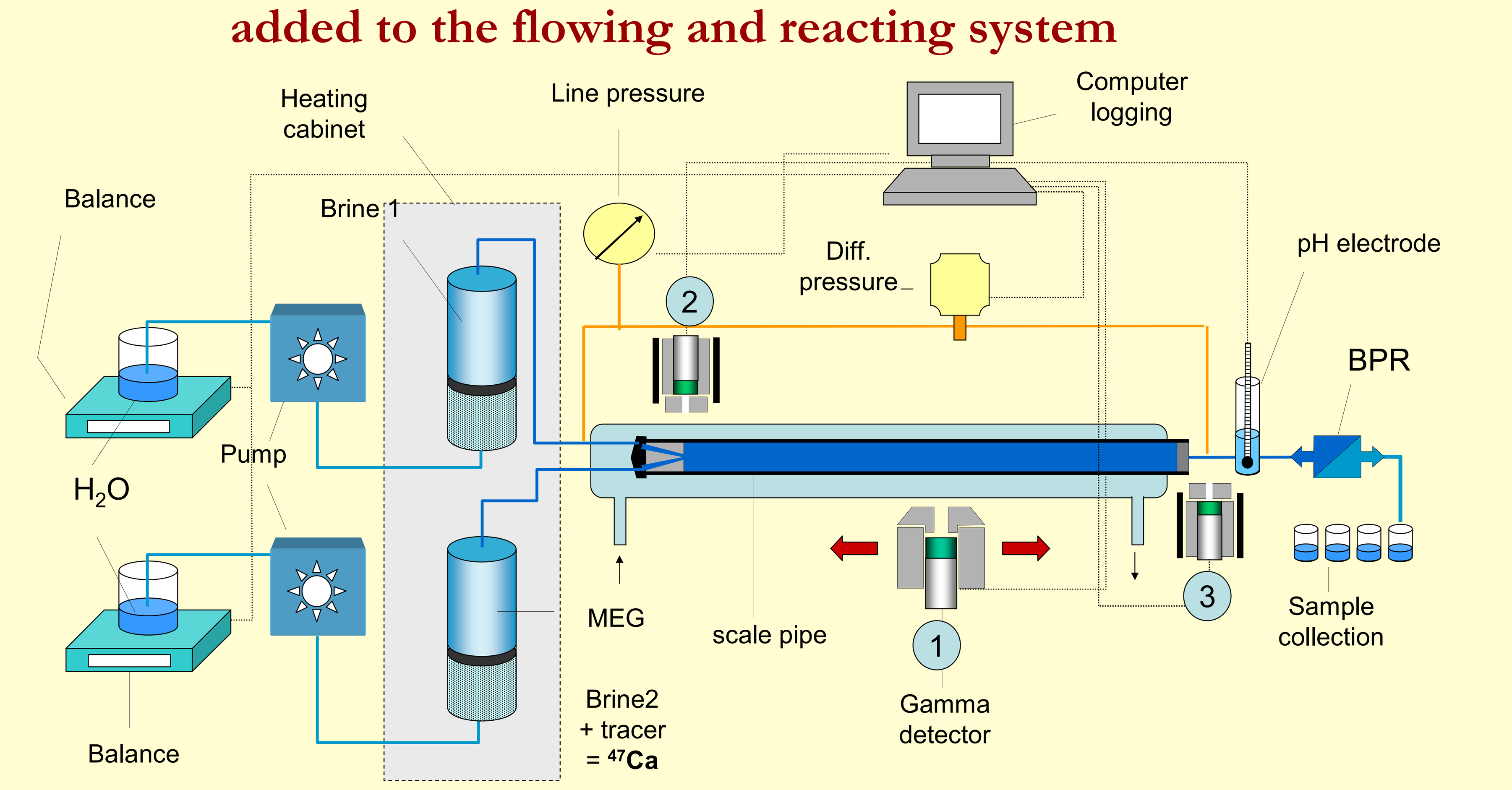
Abstract

In this work, a dynamic optimization of the fouling process in the Soult-sous-Forêts geothermal plant is being considered using the gPROMS distributed process modeling capabilities. The development of the reaction scheme is based on lab-scale experiments. *gPROMS* (**g**eneral **PRO**cess **M**odeling **S**ystem) is a simulation tool widely used for creating and executing models of any level of complexity, particularly in areas characterized by complex physical and chemical phenomena as those encountered in geothermal environments. Once an accurate predictive model is available it can be used for many different activities in analyzing and optimizing a wide range of aspects of design and operation. The result is improved design solutions, such as equipment dimensions, control tuning values and set point trajectories, with capital and operational savings that will be realized over the lifetime of the plant.

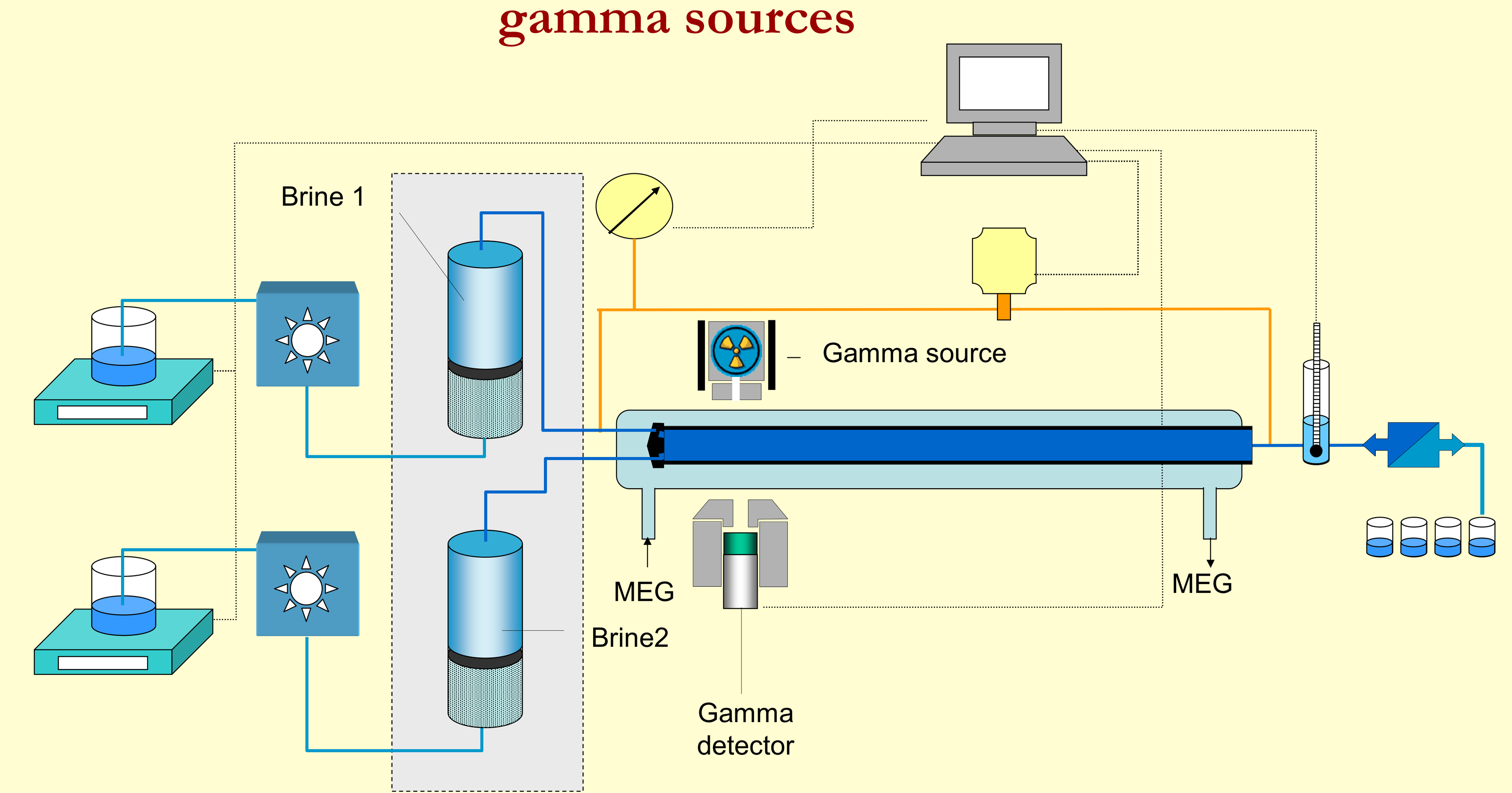
The work considers also some of the issues associated with the generation and reliability of the laboratory data used in the construction of the model. The new laboratory scale data have been acquired from a series of tube blocking experiments using nuclear techniques.

Nuclear based methods

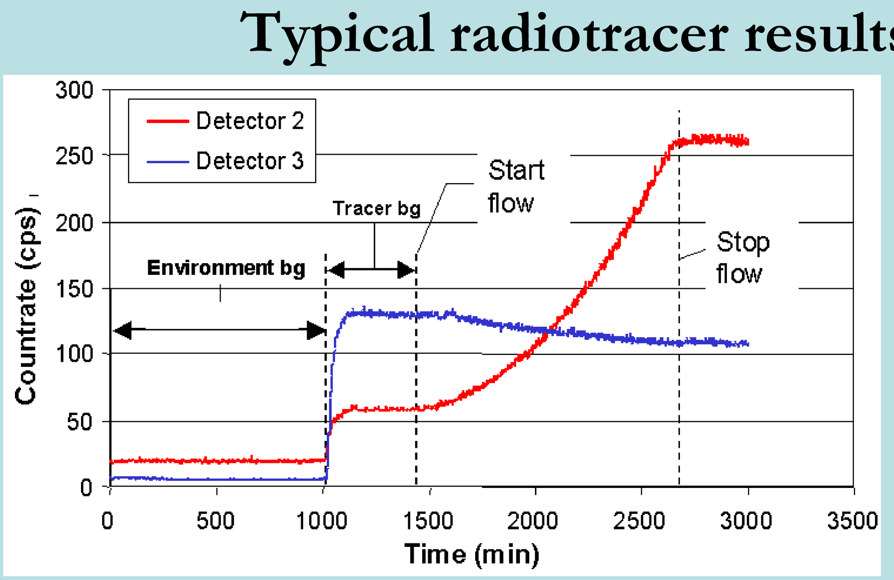
Gamma emission based on radioactive tracers added to the flowing and reacting system



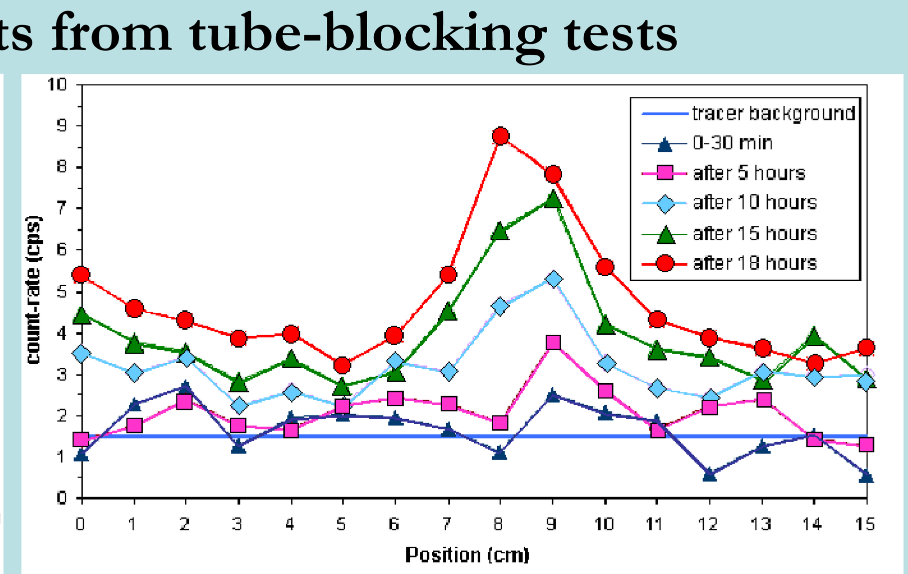
Gamma transmission based on use of external gamma sources



Typical radiotracer results from tube-blocking tests

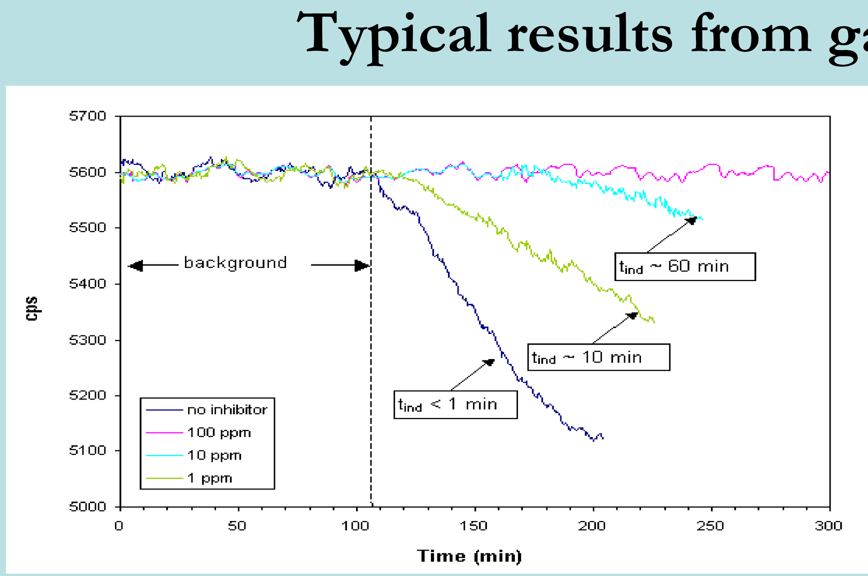


Stationary detectors' countrates

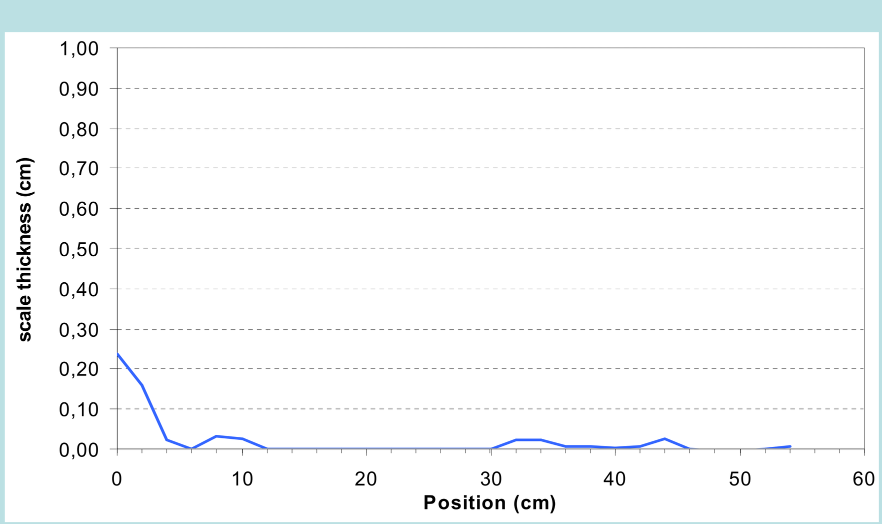


^{47}Ca deposit distribution across the tube at different time-steps

Typical results from gamma transmission tests



Gamma attenuation measurements for calcite precipitation in the presence and absence of a scale inhibitor 10cm from inlet of the tube at 185°C, 10 bars and SR=20



Scale thickness distribution across the tube

Simulations of $CaCO_3$ scale formation

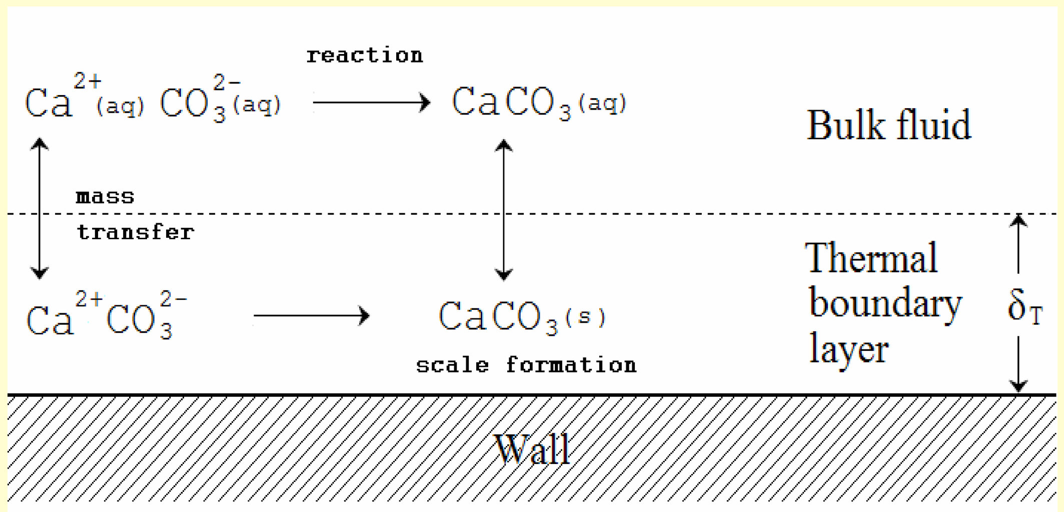
The chemical system

The main complication is the occurrence of CO2(g) in reaction [1]. The molar volume of CO2(g) varies greatly with both temperature and pressure.

$CaCO_3(s) + CO_2(g) + H_2O\ Ca^{2+}(aq) + 2HCO^{3-}(aq)$ [1]

$CaCO_3(s) + CO_2(aq) + H_2O\ Ca^{2+}(aq) + 2HCO^{3-}(aq)$ [2]

The temperature and pressure dependence of these equilibria is given from the work of Atkinson & Mecik (1994, 1997*).



The reaction/mass transfer scheme

Consider a differential element in a circular tube, where r_o is the inner radius and L is the length of the tube

Material balance for e.g. $CaCO_3$ in the the thermal boundary layer

$$\frac{\partial C_{CaCO_3}}{\partial t} + u_z \frac{\partial C_{CaCO_3}}{\partial z} = -K_p C_{Ca} - \frac{1}{\delta_T}\left[k_{mCaCO_3}\left(C_{CaCO_{3(s)}} - C_{CaCO_{3(aq)}}\right) + k_w C_{CaCO_{3(s)}}\right] + \frac{\partial}{\partial z}\left(D_{CaCO_3}\frac{\partial C_{CaCO_{3(s)}}}{\partial z}\right)$$

Reaction rate term — Mass transfer — diffusion at the axial distance

Quantifying fouling

The rate of deposition is related to the concentration of $CaCO_3(s)$ by the mass transfer coefficient k_w. The Biot number is used to express the change of heat transfer due to fouling and it is related to the rate of deposition according to:

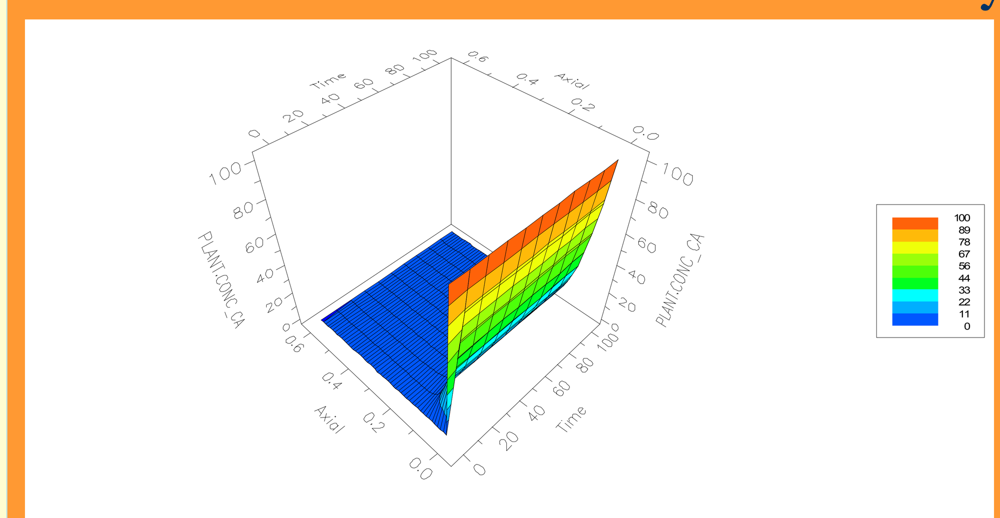
$$\frac{\partial Bi}{\partial t} = \beta k_w C_{CaCO_3}, \quad \beta \text{ is a constant}$$

Deposit thickness and mass at each position z along the heat exchanger:

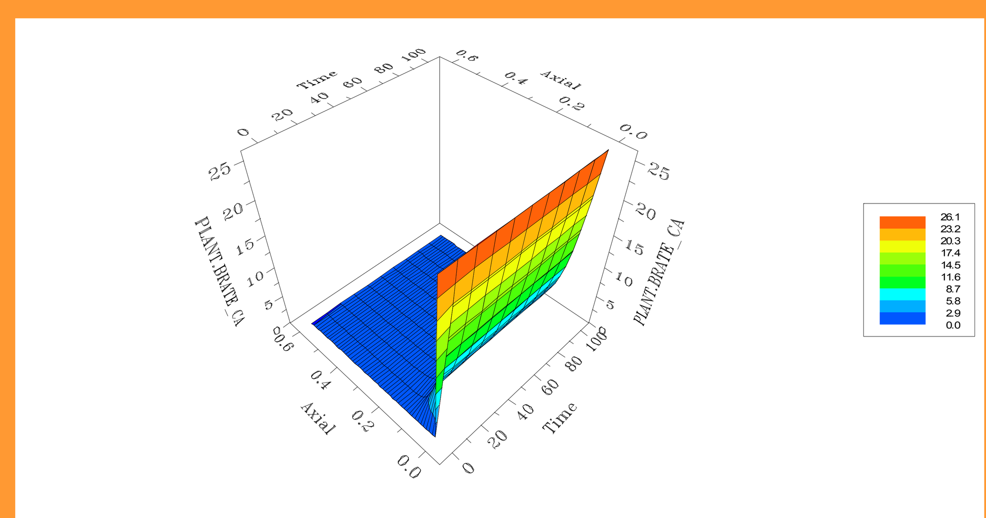
$$x_d(z) = \frac{\lambda_d Bi(z)}{U_o},$$

$$mass(z) = \frac{\lambda_d Bi(z)}{U_o}\rho_d$$

Preliminary simulation results



Consumption of Ca at the inlet of the scale tube



Reaction rate term: $-K_p C_{Ca}$

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