

# Characterization of residence time distribution in a plug-flow reactor by combining experimental studies with model-based simulations

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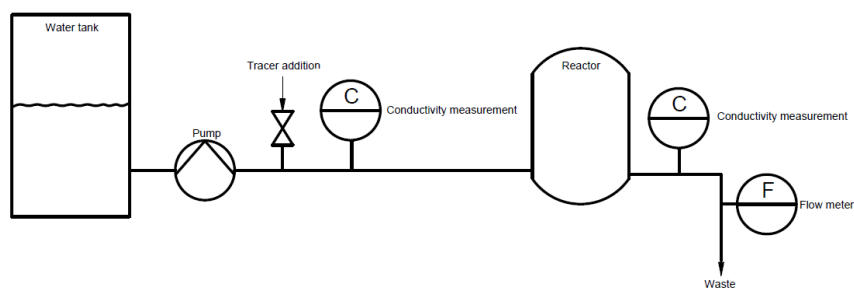
## Theoretical background and experimental setup:

The dispersion model (Taylor, 1953) is the basis for mathematical description of the residence time in a PFR. The experiments were conducted by injecting a tracer (KCl) at the reactor feed. The concentration profile at the reactor feed  $c(t)_{in}$  was measured as was the concentration profile at the reactor outlet  $c(t)_{out}$ . The residence time behaviour was calculated by convoluting the input signal  $c(t)_{in}$  with different residence time behaviours and comparing the model based output signals  $c(t)_{out,td}$  with the actual output signals  $c(t)_{out}$ . The end result was the characterisation of the PFR with the Bodenstein-Number  $Bo$  which is a measure for the deviation from an ideal PFR.

The Goals of the experiments were as follows:

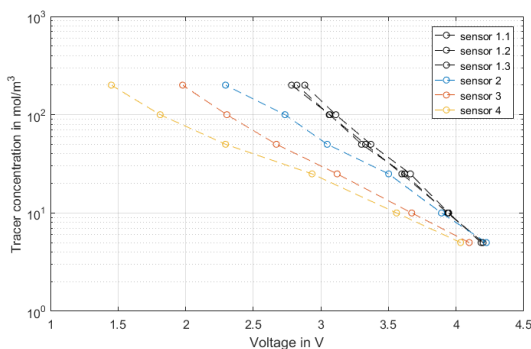
- Characterisation of the residence time behaviour of a PFR in different flow states (laminar, turbulent)
- Comparison of the results with a MATLAB based simulation (dispersion-model)
- Quantification of the influence of the input signal  $c(t)_{in}$  on the output signal  $c(t)_{out}$ .

Figure 1. Flow Chart of the experimental setup



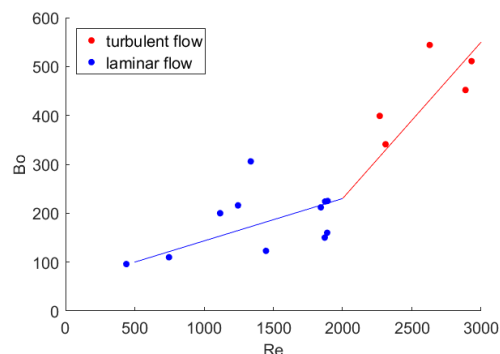
## Results:

Figure 2. Calibration curves of conductivity metres



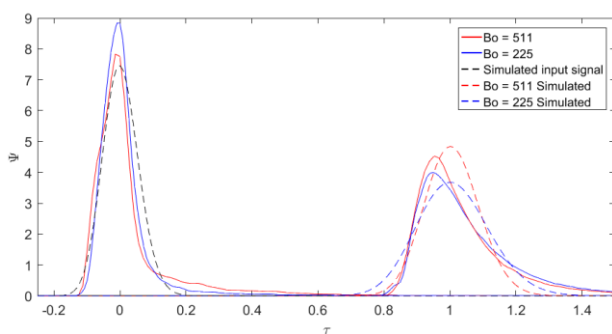
The conductivity metres were calibrated before each experiment. 4 were used in total. Sensor 1 was calibrated three times to ensure reproducibility of the results. The calibration range was between 0.005 M and 0.2 M.

Figure 3. Experimental results



The results show that a change in residence time behavior happens at around  $Re = 2300$ . The backmix in the PFR increases as the flow changes from laminar to turbulent as expected.

Figure 4. Comparison between experiment and simulation



The dispersion model was used to simulate the experiments in MATLAB. The experimental output signals are slightly shifted to the left. This is probably because of the simplifications included in the dispersion model.

## Conclusions:

It is not enough to look at the concentration profile at the reactor outlet  $c(t)_{out}$  to determine the residence time behaviour unless you can ensure an input concentration profile  $c(t)_{in}$  in shape of a Dirac delta function.

Without a numerical analysis a good approximation for the  $Bo$ -Number of the can be gained with the following formula ( $Bo > 100$ ):

$$Bo = \frac{2}{\frac{2}{B_{out}} - \sigma_{in}^2}$$

$Bo$  ist the approximated  $Bo$ -Number of the system.

$B_{out}$  ist he  $Bo$ -Number calculated only from the output signal  $c(t)_{out}$  as if  $c(t)_{in}$  is in shape of a Dirac delta function.

$\sigma_{in}$  is the standard deviation of the dimensionless input signal  $c(t)_{in}$  written as  $\Psi(\tau)$  which can be seen in Figure 4.