From Real Time Process Data to Advanced Optimization Control
and Improved Mass, Material and Energy Balances
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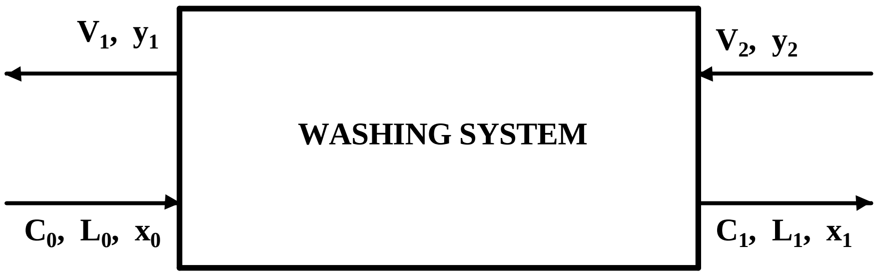
# From real-time process data to advanced optimization control and improved mass, material and energy balances

# Washing – an example

## Basic parameters

$$L_0 = (100 - C_0)/C_0 \qquad L_1 = (100 - C_1)/C_1$$




$$L_0 + V_2 = L_1 + V_1 \qquad \mu_{L0} + \mu_{V2} = \mu_{L1} + \mu_{V1}$$

$$L_0x_0 + V_2y_2 = L_1x_1 + V_1y_1 \qquad \mu_{L0}\mu_{x0} + \mu_{V2}\mu_{y2} = \mu_{L1}\mu_{x1} + \mu_{V1}\mu_{y1}$$



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# Data reconciliation

## Objective functions

Sequential method

Flows

$$J_f = \frac{1}{2}\left( \frac{(\mu_{L_0} - \overline{L}_0)^2}{s_{L_0}^2} + \frac{(\mu_{L_1} - \overline{L}_1)^2}{s_{L_1}^2} + \frac{(\mu_{V_1} - \overline{V}_1)^2}{s_{V_1}^2} + \frac{(\mu_{V_2} - \overline{V}_2)^2}{s_{V_2}^2} \right)$$

Solutes

$$J_s = \frac{1}{2}\left( \frac{(\mu_{x_0} - \overline{x}_0)^2}{s_{x_0}^2} + \frac{(\mu_{x_1} - \overline{x}_1)^2}{s_{x_1}^2} + \frac{(\mu_{y_1} - \overline{y}_1)^2}{s_{y2}^2} + \frac{(\mu_{y_2} - \overline{y}_2)^2}{s_{y_2}^2} \right).$$

The sample averages, the sample standard deviations and the adjusted flows and solute concentrations or contents.

# Solving objective functions (linear system)

Inserting the adjusted flow balance equation to the objective function and demanding

$$\frac{\partial J_f}{\partial \mu_{L_0}} = 0, \qquad \frac{\partial J_f}{\partial \mu_{V_1}} = 0, \qquad \frac{\partial J_f}{\partial \mu_{V_2}} = 0,$$

one gets the adjusted flows. Then, inserting the adjusted solute material balance equation to the objective function and demanding

$$\frac{\partial J_s}{\partial \mu_{x_0}} = 0, \qquad \frac{\partial J_s}{\partial \mu_{y_1}} = 0, \qquad \frac{\partial J_s}{\partial \mu_{y_2}} = 0,$$

one gets the adjusted solute concentrations or contents.

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# Data reconciliation

## Objective function

Simultaneous method

Flows and solutes

$$J = \frac{1}{2}\left(\frac{(\mu_{L_0} - \overline{L}_0)^2}{s_{L_0}^2} + \frac{(\mu_{L_1} - \overline{L}_1)^2}{s_{L_1}^2} + \frac{(\mu_{V_1} - \overline{V}_1)^2}{s_{V_1}^2} + \frac{(\mu_{V_2} - \overline{V}_2)^2}{s_{V_2}^2} + \ldots\right.$$

$$\left.\ldots + \frac{(\mu_{x_0} - \overline{x}_0)^2}{s_{x_0}^2} + \frac{(\mu_{x_1} - \overline{x}_1)^2}{s_{x_1}^2} + \frac{(\mu_{y_1} - \overline{y}_1)^2}{s_{y2}^2} + \frac{(\mu_{y_2} - \overline{y}_2)^2}{s_{y_2}^2}\right)$$

The sample averages, the sample standard deviations and the adjusted flows and solute concentrations or contents.

# Solving objective function (non-linear system)

Inserting the adjusted flow and solute material balance equations to the objective function and demanding

$$\frac{\partial J}{\partial \mu_{L_0}} = 0, \quad \frac{\partial J}{\partial \mu_{V_1}} = 0, \quad \frac{\partial J}{\partial \mu_{V_2}} = 0, \quad \frac{\partial J}{\partial \mu_{x_0}} = 0, \quad \frac{\partial J}{\partial \mu_{y_1}} = 0, \quad \frac{\partial J}{\partial \mu_{y_2}} = 0,$$

one gets the adjusted flows and solute concentrations or contents.

From the adjusted parameters one can calculate the dilution factor and parameters describing the efficiency of a washer or washing system.

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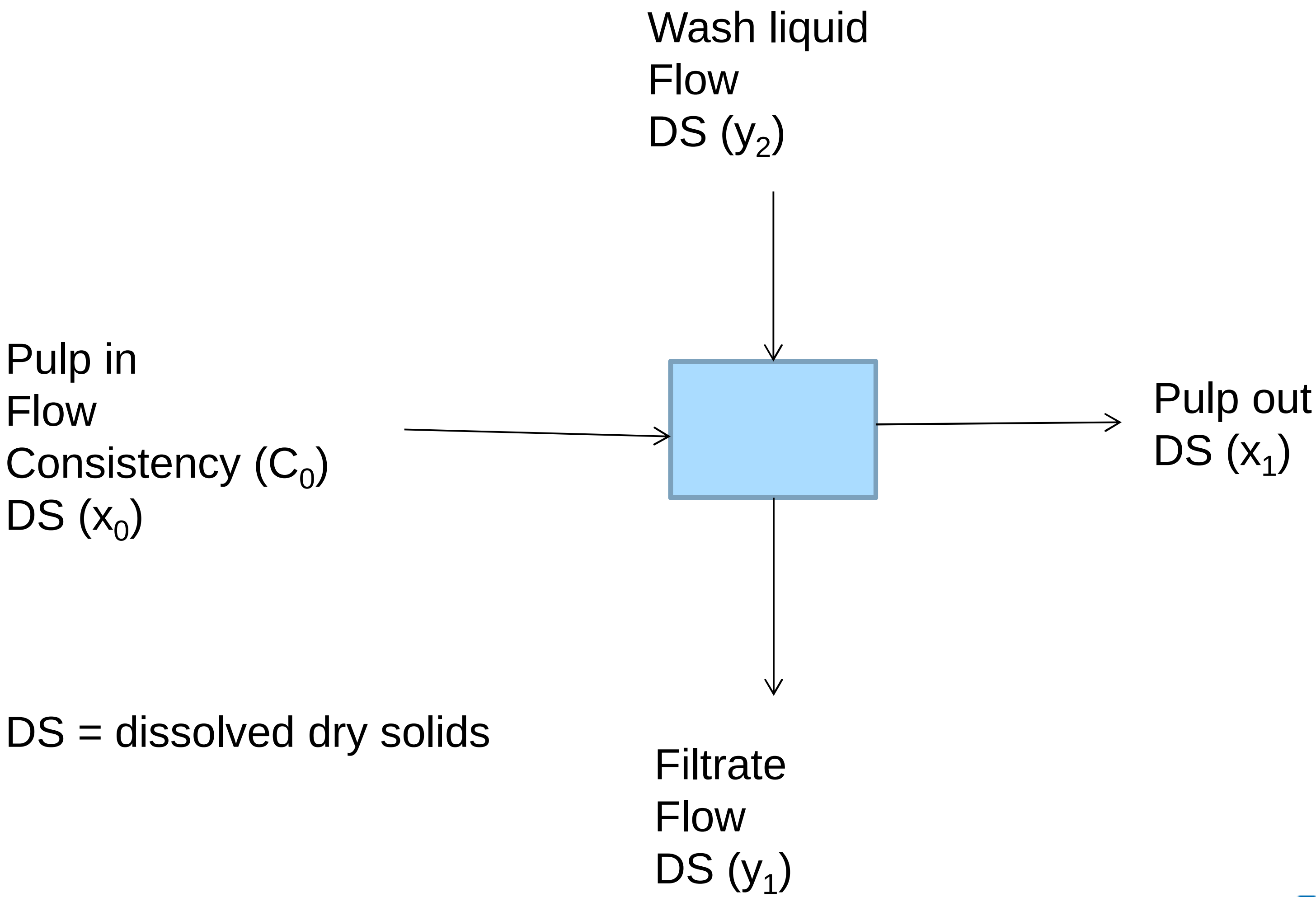
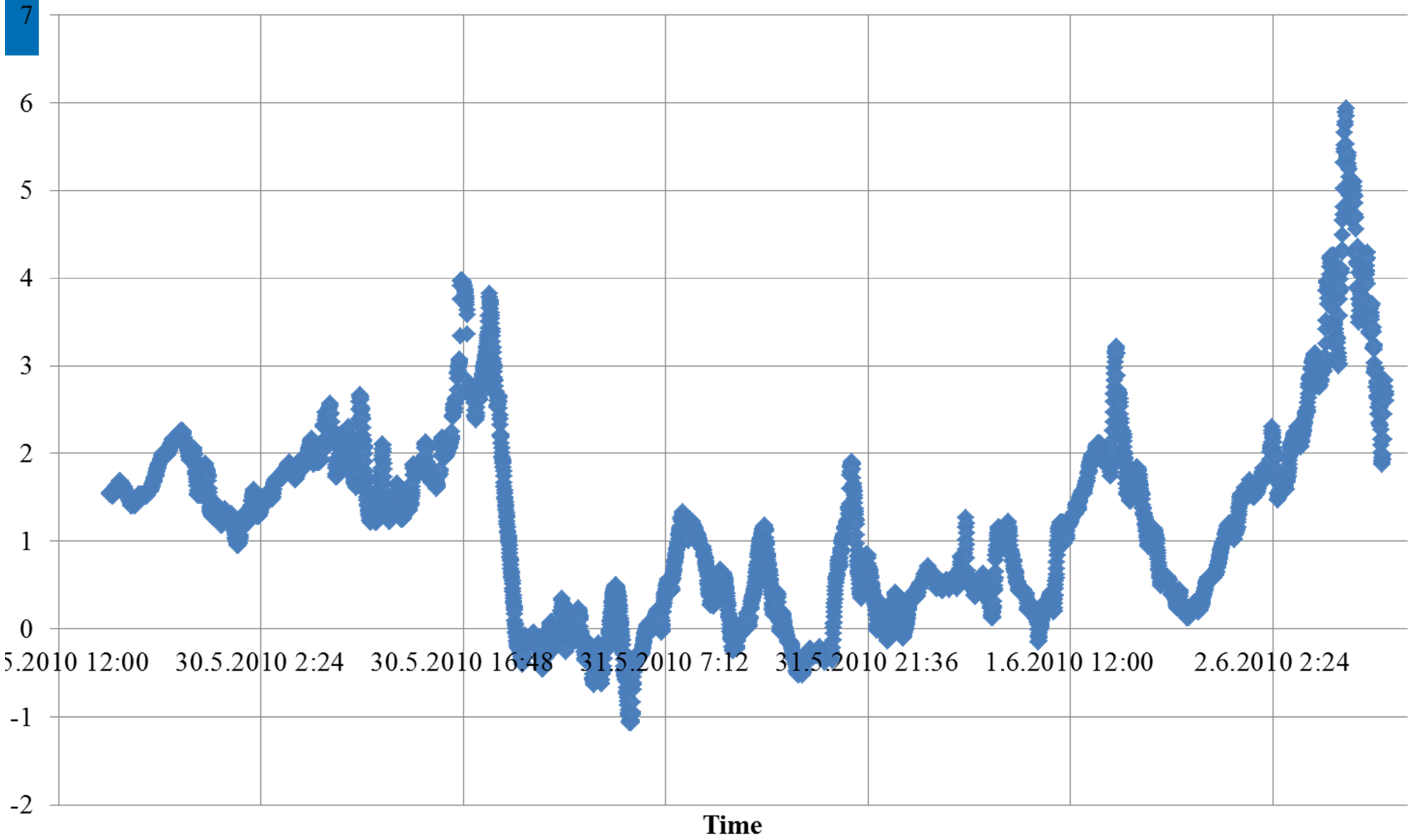
# Measured parameters around a washer – an example



# Online DF of a washer

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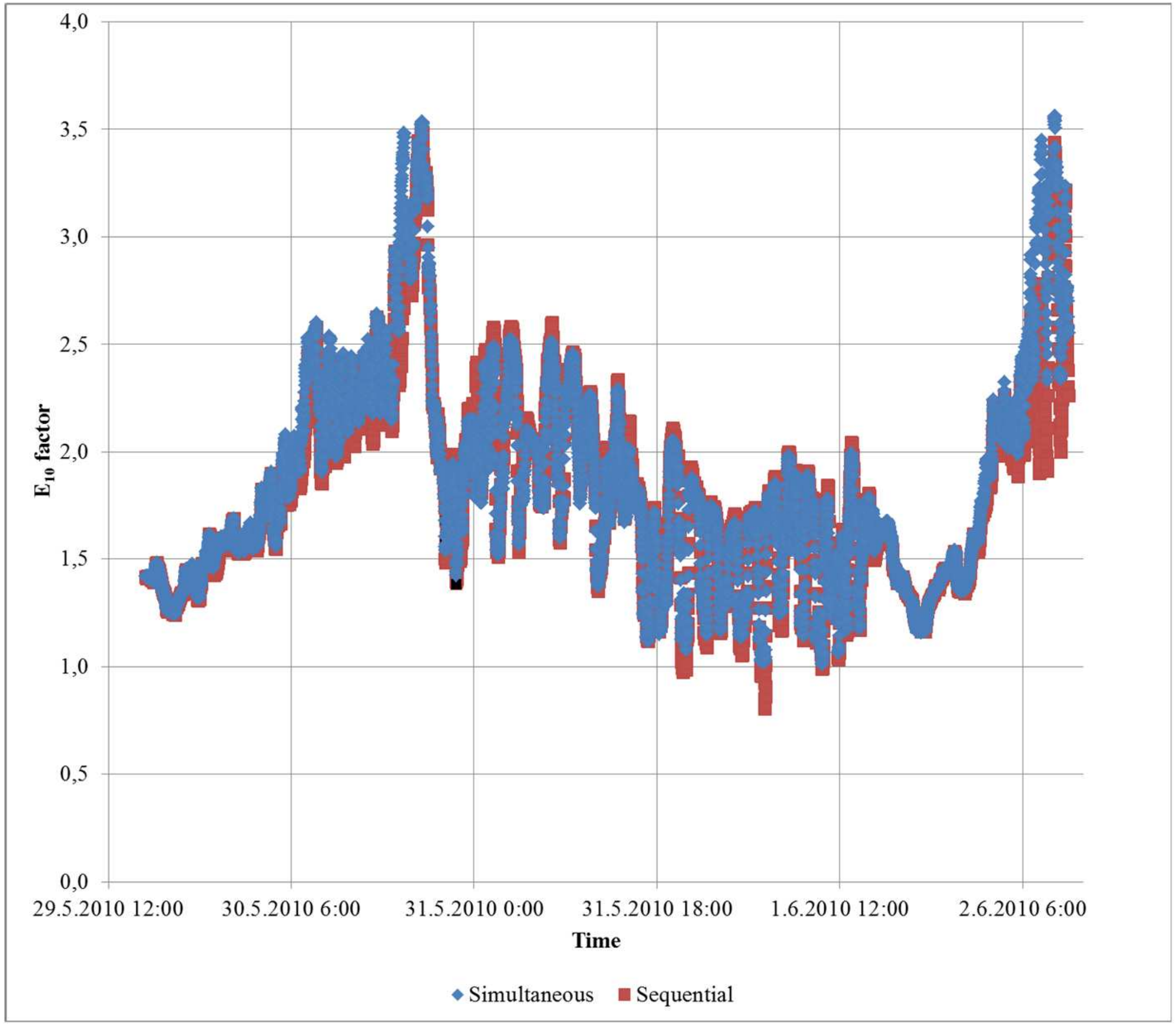
# Online $E_{10}$ factor of a washer



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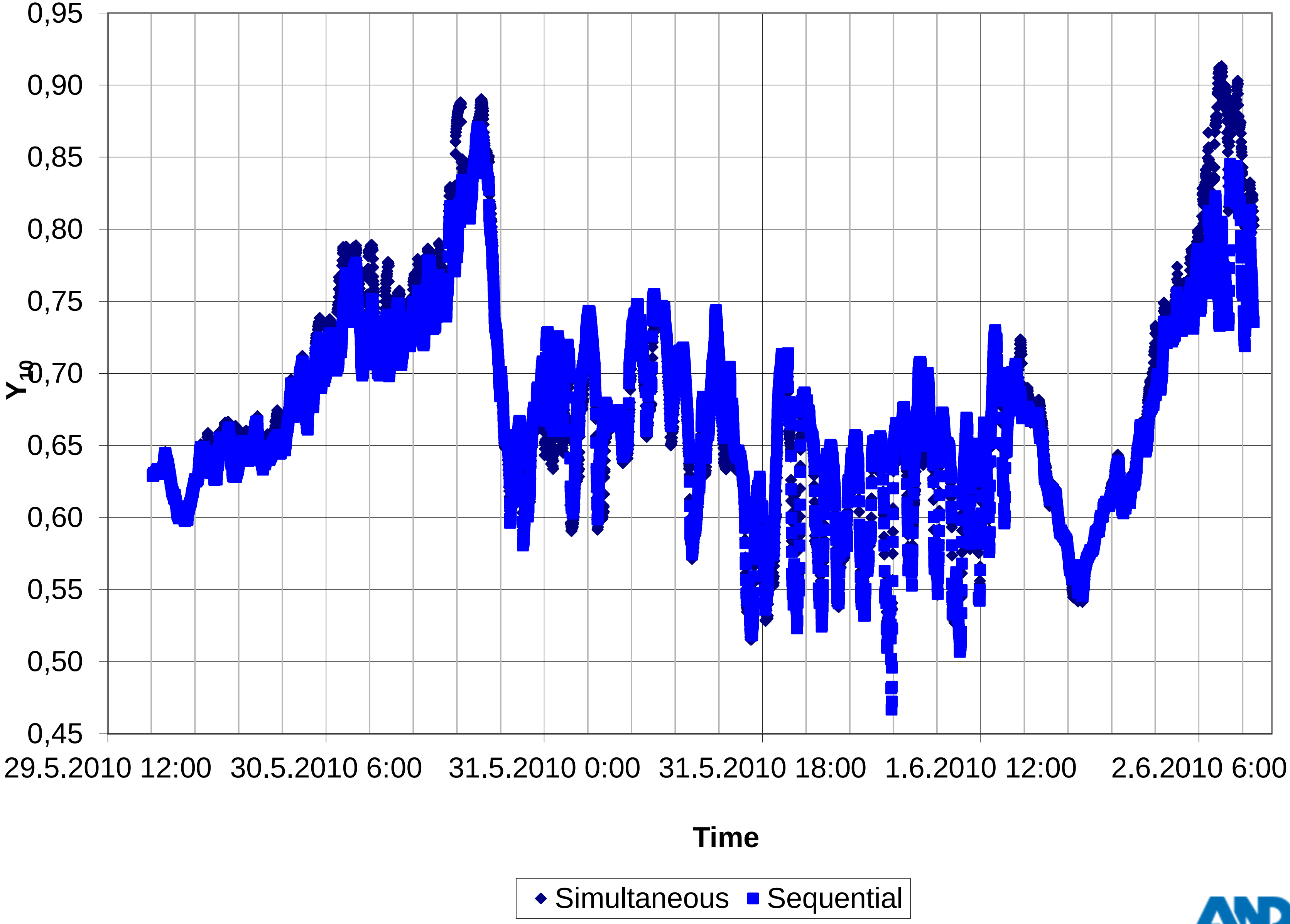
# Online standardized wash yield $Y_{10}$ value of a washer

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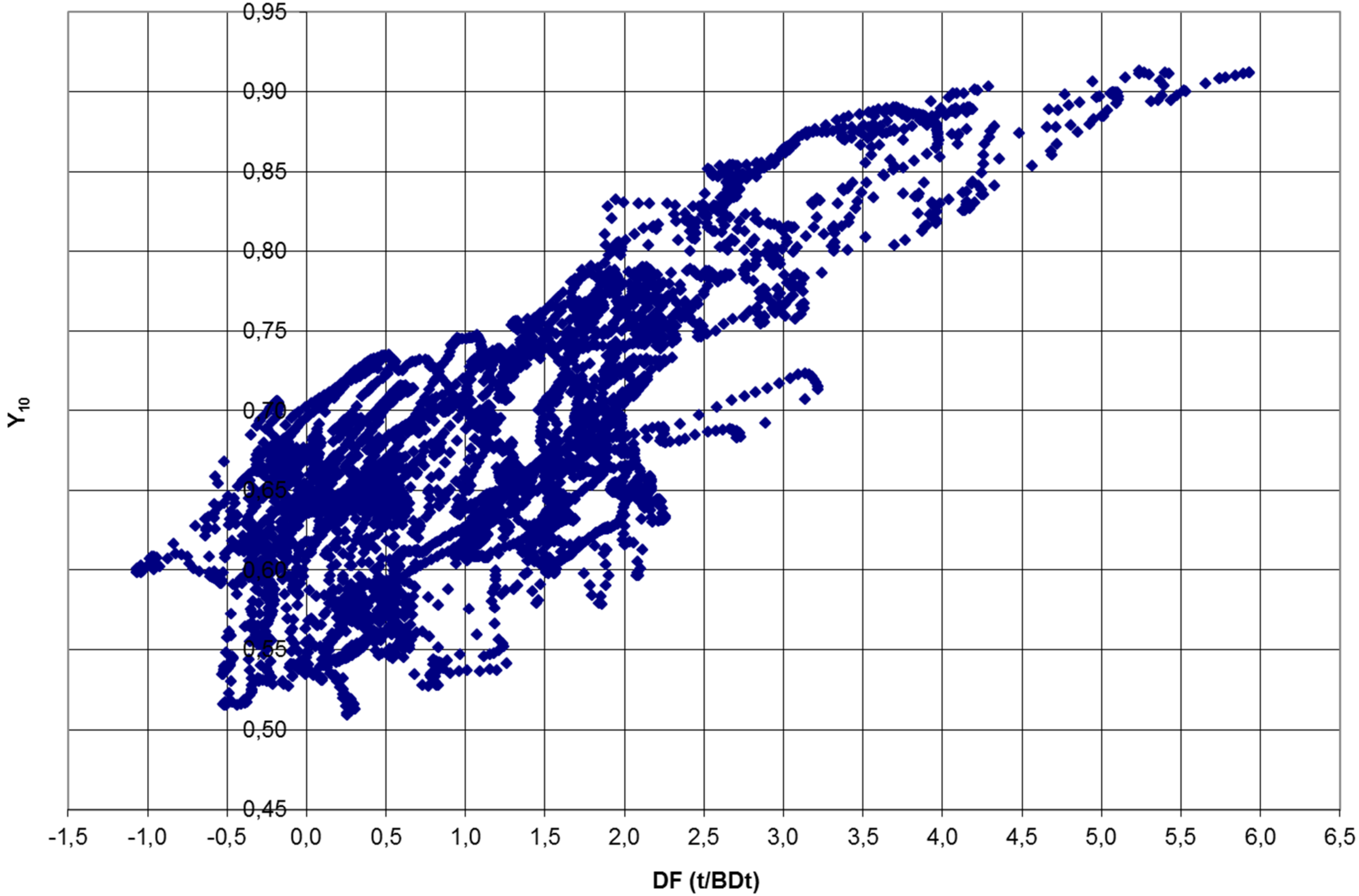
# Standardized wash yield $Y_{10}$ value of a washer

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# Optimal DF of a washing line (simplified)

A simplified cost function of the washing and the evaporation

$$H = H_1 + H_2 = \frac{(Q_0 + DF)c_{out} - m_{1,DS}}{E_1 c_{out}} h_1 + m_{2,DS} h_2 = \ldots$$

$$\ldots = \frac{(Q_0 + DF)c_{out} - (M_{DS} - m_{2,DS})}{E_1 c_{out}} h_1 + m_{2,DS} h_2$$

The optimal DF is solved from the equation

$$\frac{h_1}{E_1} + \frac{dm_{2,DS}}{dDF}\left(\frac{h_1}{E_1 c_{out}} + h_2\right) = 0$$



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