HMI³ Optimization Approach for Pulp & Paper Industry

Added Value by Optimal Process Control

Andreas Roither-Voigt

Tieto, ZSPM Manufacturing, Retail and Logistics
andreas.roither-voigt@tieto.com

Optimization Targets

- Production Costs & Savings
- Safety of operation
- Production Capacity (of existing assets)
- Product Quality
- Energy Efficiency
- Raw material yield
- Robustnes of operation
- Flexibility of production

HMI³ Optimizers Overview
A systematic and modular large scale approach

Available Optimizations Modules:

- Site-Balance Optimization
- O_2-Delignification + Bleaching Plant
- Continuous Digester (Kamyr)
- Steam & Electricity Production (Forecast and short term optimization intraday)
- Paper Machine Settings for Grade & Quality Control
- Evaporator Washing Strategy
- Recovery Boiler Operation at full load
- Drying Cost & Energy Efficiency Optimization of Yankee PMs

Optimization Approach

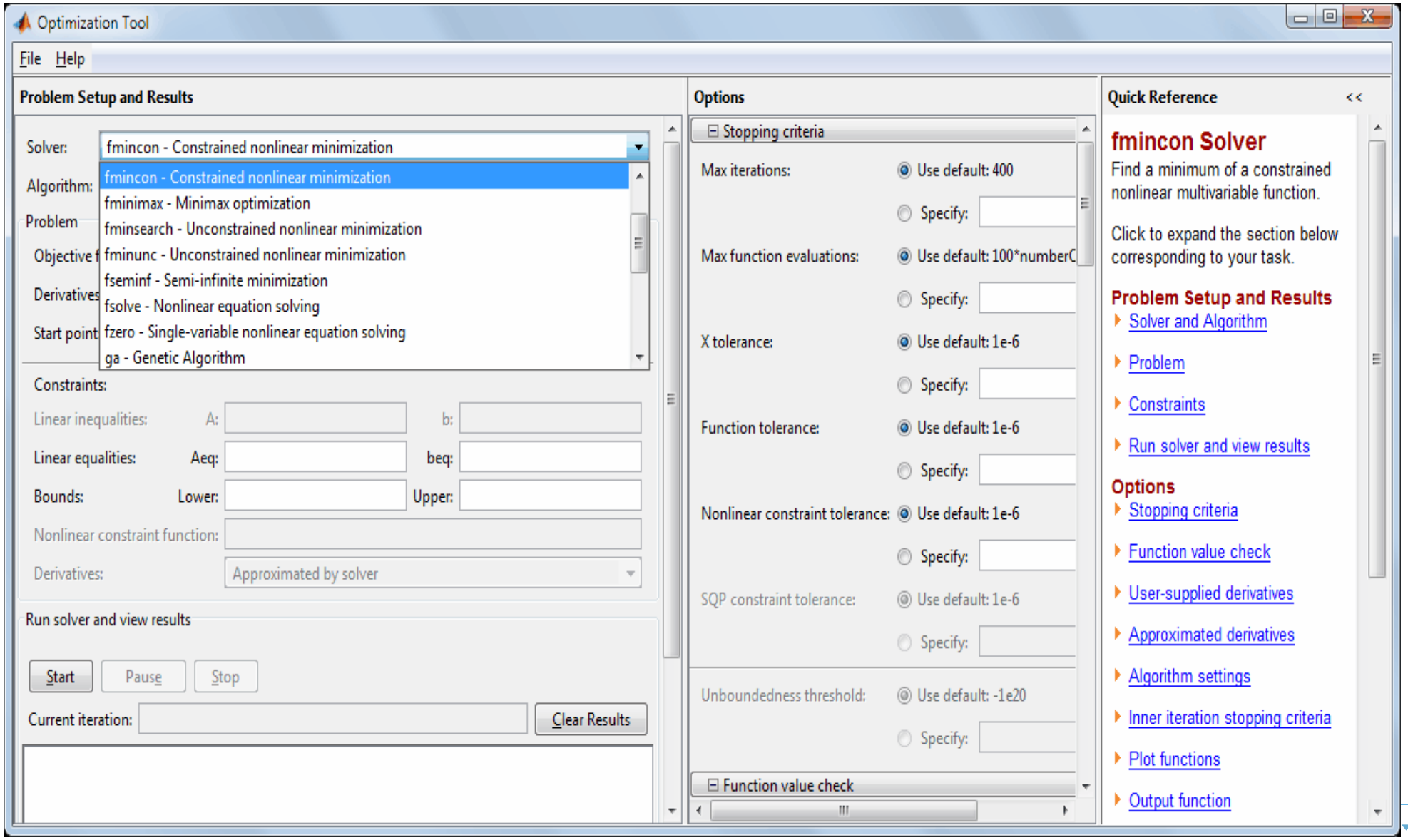
1. Development of a **robust process model**
2. **Degrees of Freedom** analysis (to manipulate the process)
3. Definition of **objectives**
4. Definition of **constraints**
5. Definition of **weights**
6. Definition of a **objective function**
7. Definition of **Jacoby function** (Performance boost)
8. Selection of **appropriate solver**

Optimization Approach – Larges Scale

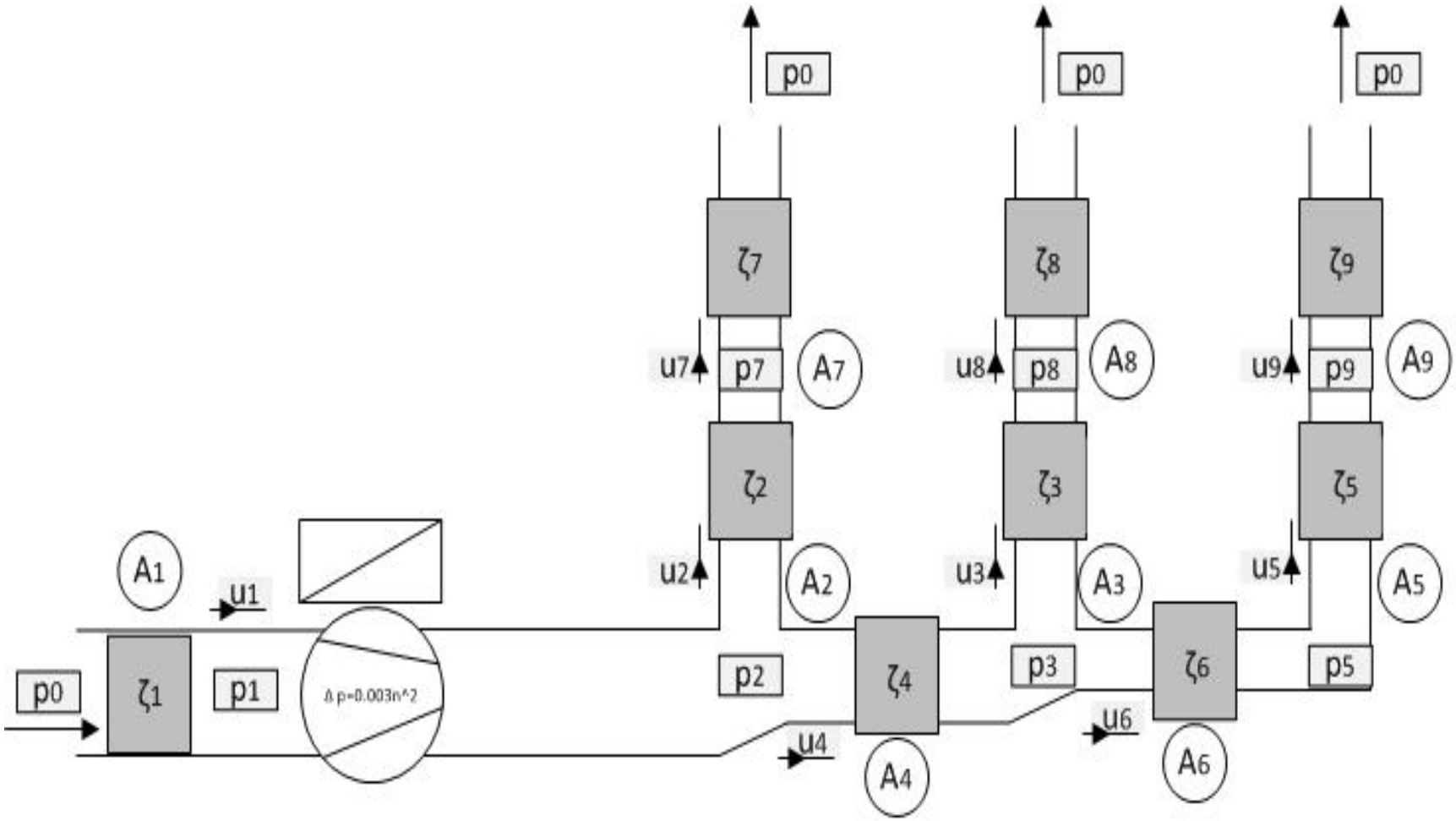
1. Up to 1000‘s degrees of freedom (DoF * Time Horizon)
2. Up to 20 terms in objective function (very flexible)
3. Up to 1000‘s of weights, constraints, setpoints (in horizon)
4. Up to 15min calculation time for large scale optimization problem solution

Much Experience and know-how required for setup of high performance large scale optimization solutions.

Optimization Toolset



Optimization for Solving Large Balance Networks

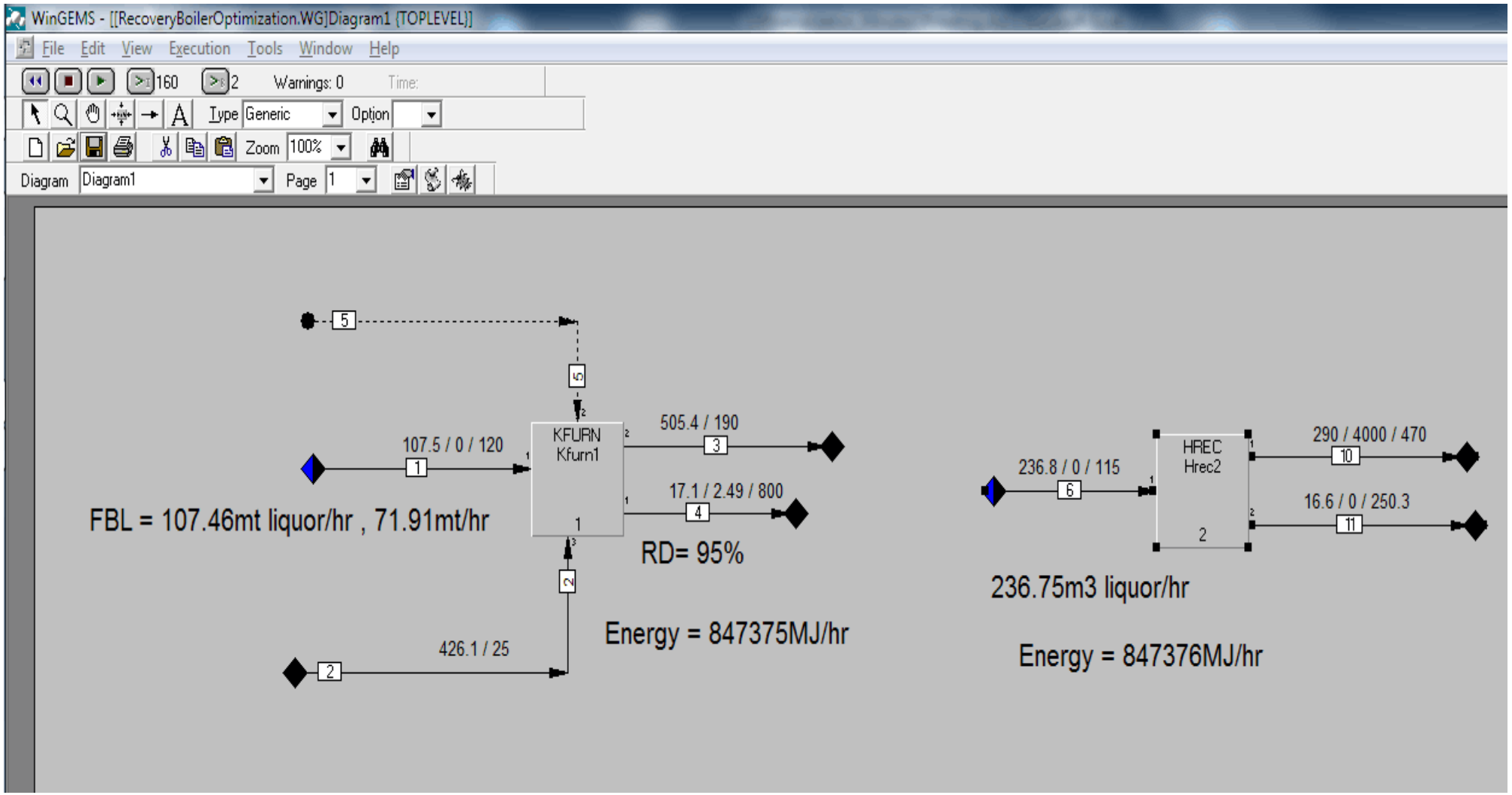


Optimization for Solving Large Balance Networks

```
function [F,J] = pipesystem(x,c)
%c=[p0 zeta1 zeta2 zeta3 zeta4 zeta5 zeta6 zeta7 zeta8 zeta9 rho1 rho2 n];
% c(1) c(2)  c(3)  c(4)  c(5)  c(6)  c(7)  c(8)  c(9) c(10) c(11) c(12) c(13)
% x = [p1 p2 p3 p5 p7 p8 p9 u1 u2 u3];

F =[c(1)-x(1)-c(2)*c(11)*0.5*x(8)^2;
    x(1)-x(2)+0.003*c(13)^2;
    x(5)-x(2)+c(3)*c(11)*0.5*x(9)^2;
    x(6)-x(3)+c(4)*c(11)*0.5*x(10)^2;
    x(3)-x(2)+c(5)*c(11)*0.5*(x(8)-x(9))^2;
    x(7)-x(4)+c(6)*c(11)*0.5*(x(8)-x(9)-x(10))^2;
    x(4)-x(3)+c(7)*c(11)*0.5*(x(8)-x(9)-x(10))^2;
    c(1)-x(5)+c(8)*c(11)*0.5*x(9)^2;
    c(1)-x(6)+c(9)*c(11)*0.5*x(10)^2;
    c(1)-x(7)+c(10)*c(11)*0.5*(x(8)-x(9)-x(10))^2]


J =[-1 0 0 0 0 0 0 -c(2)*c(11)*x(8) 0 0;
   1 -1 0 0 0 0 0 0 0 0;
   0 -1 0 0 1 0 0 0 c(3)*c(11)*x(9) 0;
   0 0 -1 0 0 1 0 0 0 c(4)*c(11)*x(10);
   0 -1 1 0 0 0 0 c(5)*c(11)*(x(8)-x(9)) c(5)*c(11)*(x(9)-x(8)) 0;
   0 0 0 -1 0 0 1 c(6)*c(11)*(x(8)-x(9)-x(10)) c(6)*c(11)*(x(9)+x(10)-x(8)) c(6)*c(11)*(x(10)+x(9)-x(8));
   0 0 -1 1 0 0 0 c(7)*c(11)*(x(8)-x(9)-x(10)) c(7)*c(11)*(x(9)+x(10)-x(8)) c(7)*c(11)*(x(10)+x(9)-x(8));
   0 0 0 0 -1 0 0 0 c(8)*c(11)*x(9) 0;
   0 0 0 0 0 -1 0 0 0 c(9)*c(11)*x(10);
   0 0 0 0 0 0 -1 c(10)*c(11)*(x(8)-x(9)-x(10)) c(10)*c(11)*(x(9)+x(10)-x(8)) c(10)*c(11)*(x(10)+x(9)-x(8))];

% Optimization
options=optimset('Jacobian','on');
[x,fval,exitflag,output] = fsolve(@(x)pipesystem(x,c),x0);
```

Equation system solved in 0.67s

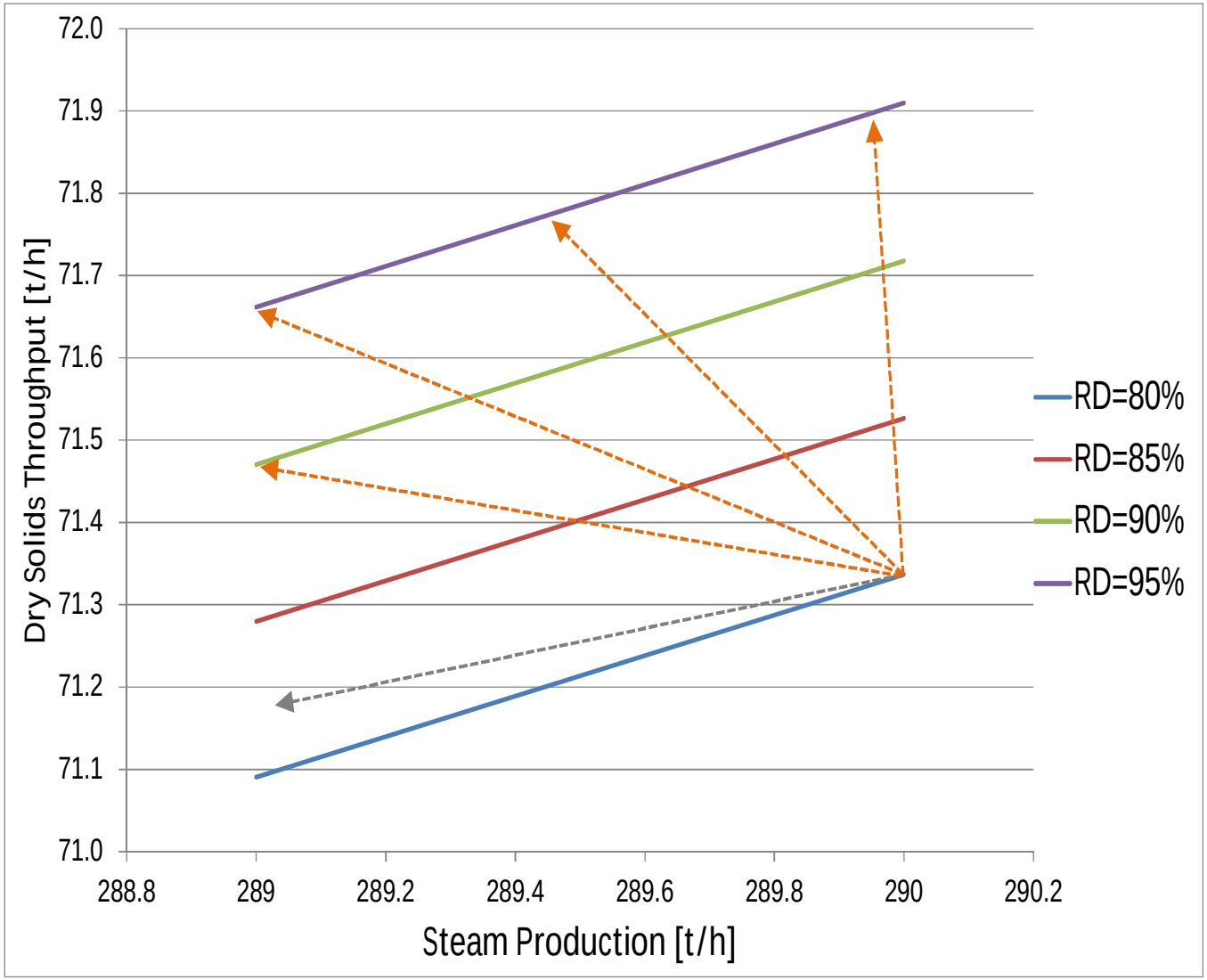
Recovery Boiler Optimization



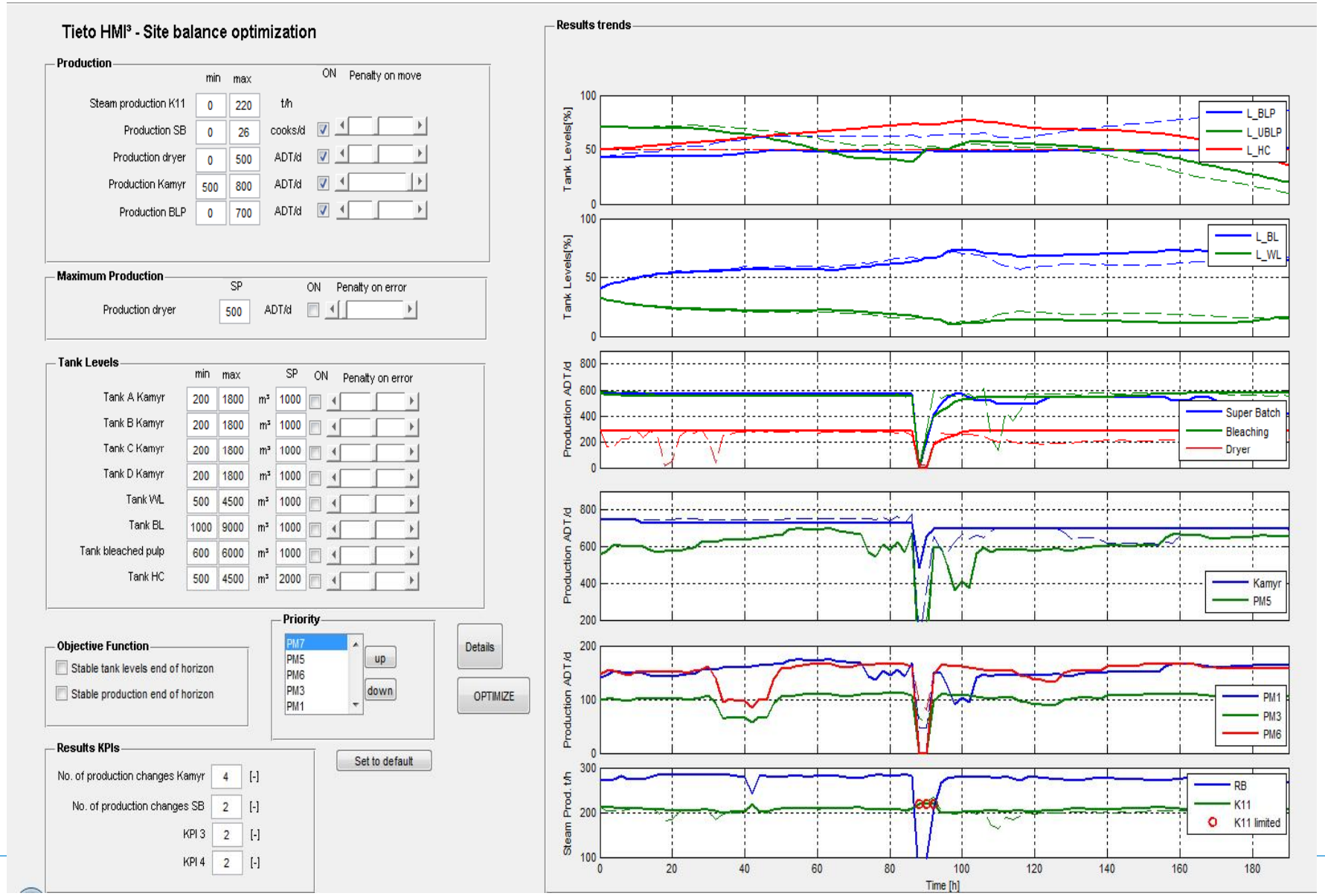
Recovery Boiler Optimization

Process Variable	Engineering Unit	Value	Value	Value	Value	Value	Value	Value	Value
RB steam flow	mt/hr	290.00	290.00	290.00	290.00	289.00	289.00	289.00	289.00
Black liquor consumption	mt liquor/hr	106.60	106.88	107.17	107.46	106.23	106.52	106.80	107.09
Dry Solids per hour	mt/hr	71.34	71.53	71.72	71.91	71.09	71.28	71.47	71.66
Reduction degree	%	80.00	85.00	90.00	95.00	80.00	85.00	90.00	95.00

Recovery Boiler Optimization



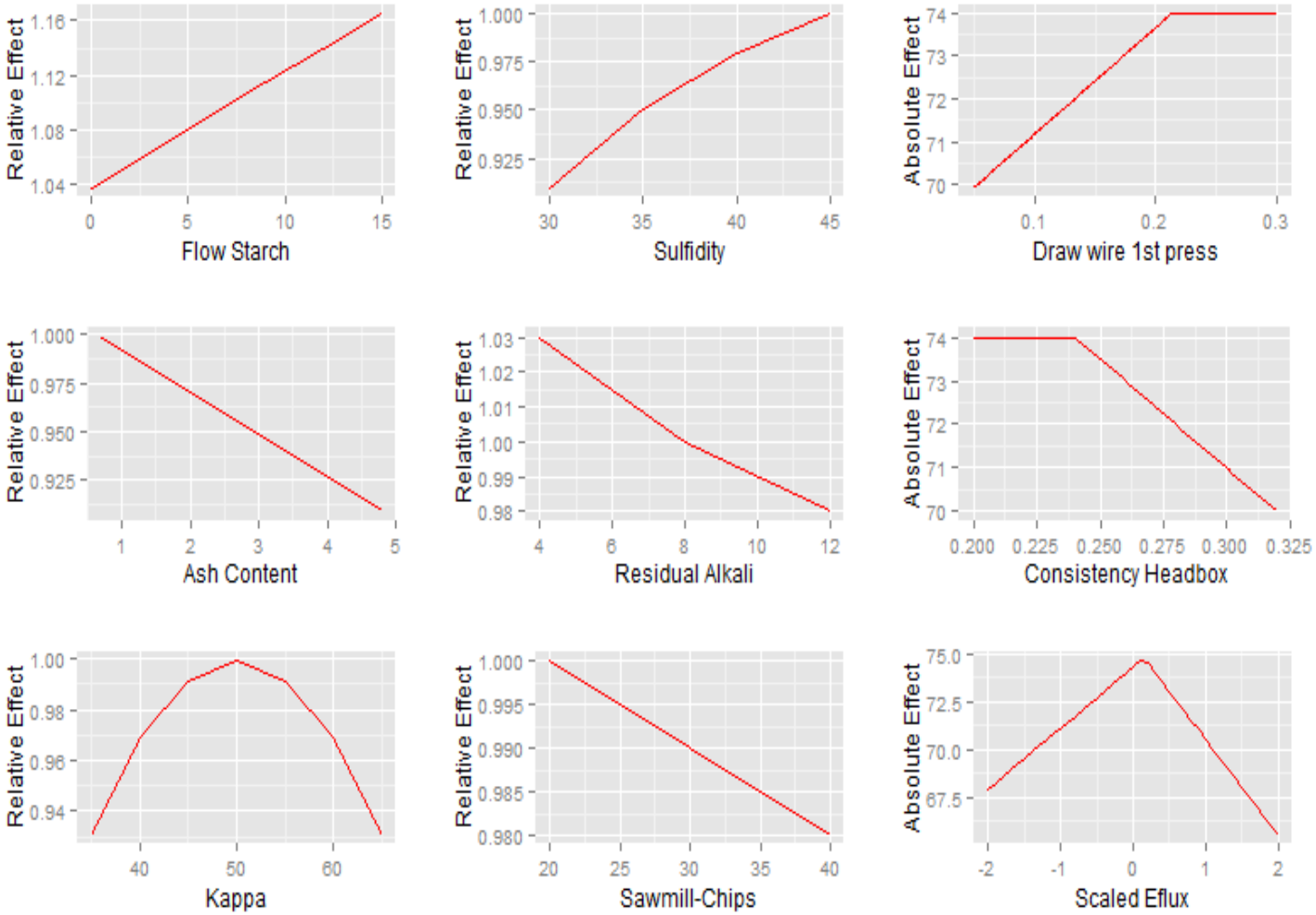
Optimization of integrated Pulp & Paper Mill



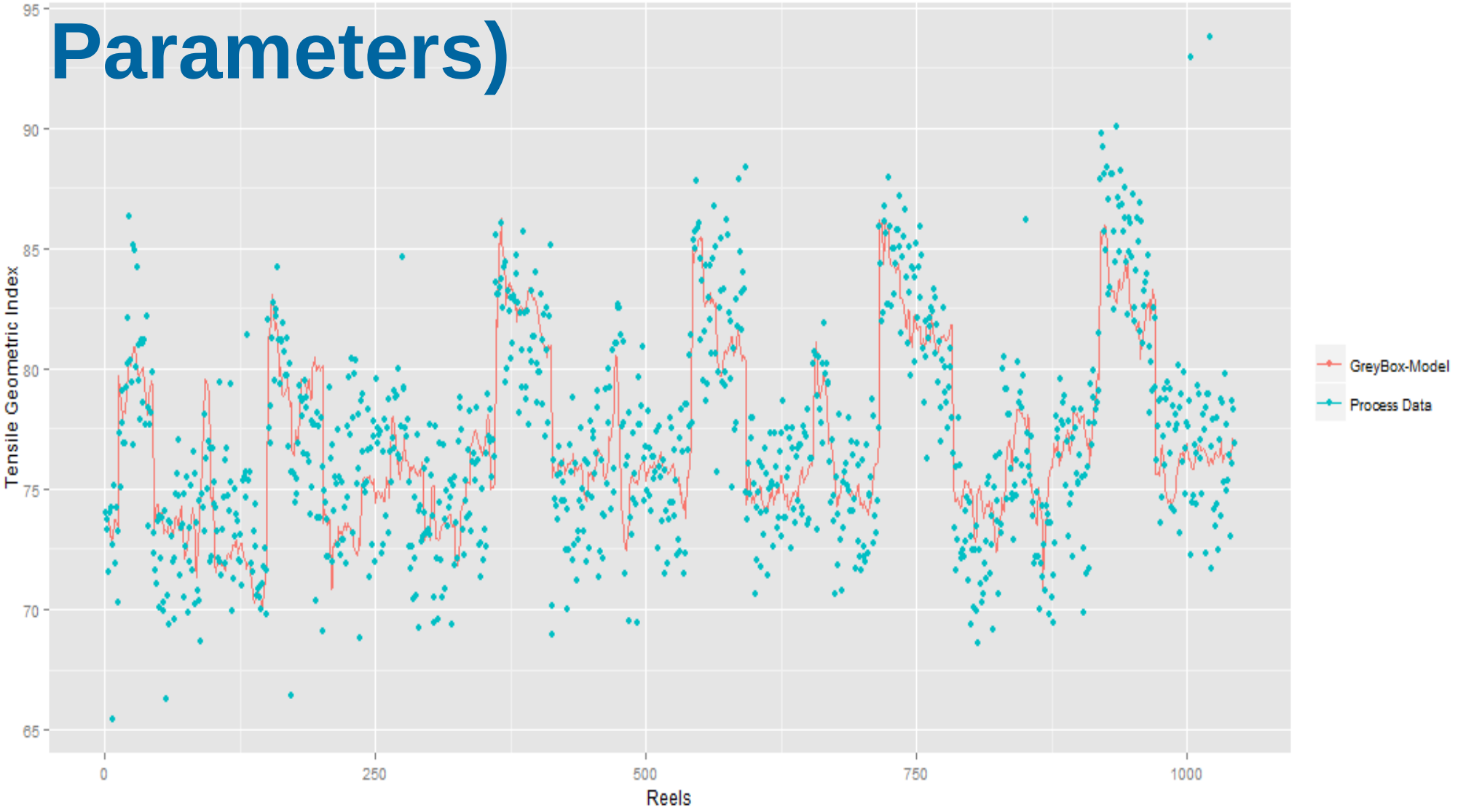
Paper Machine Optimization (Quality)

Quality Parameters
Tensile Strength Index (MD, CD, Geometric mean)
Stretch Elongation (MD, CD)
Burst Index
Porosity
COBB
Others

Tensile Index (Influence Par

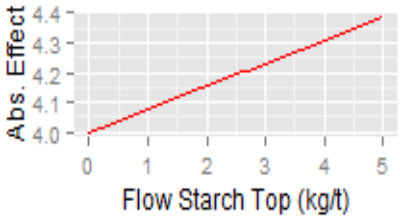


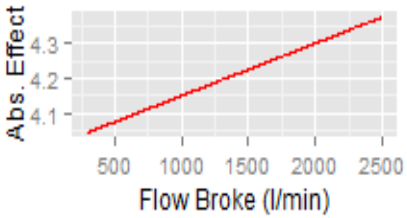
Tensile Index (Influence Parameters)

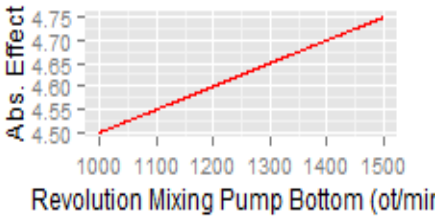


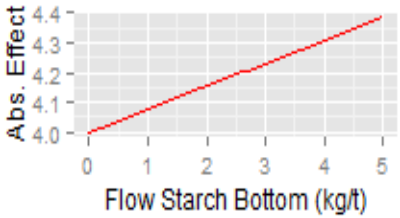
Paper Machine Optimization (Burst Index)

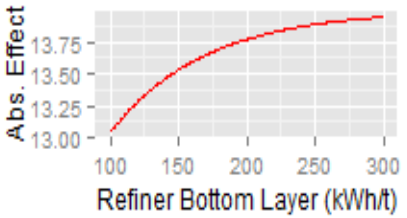
Influence Parameters

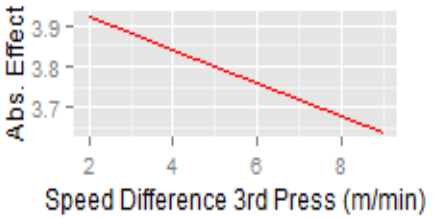


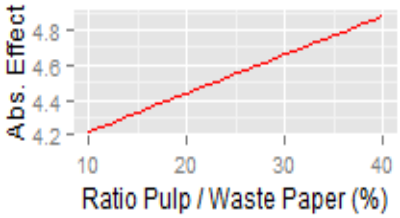


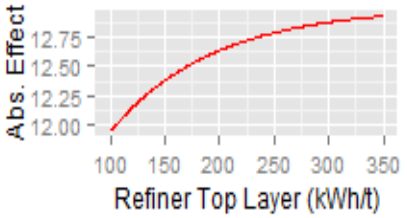


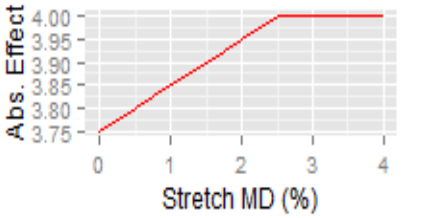


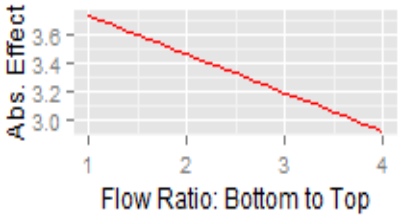


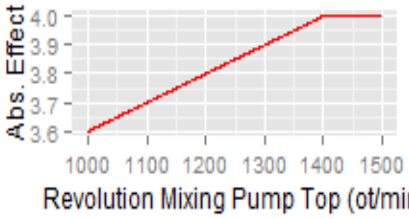


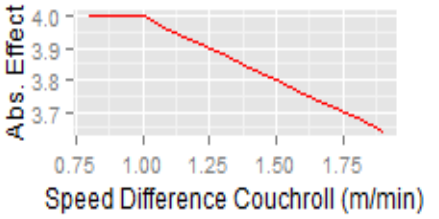












HMI³ task force Optimization

Optimization Team @Tieto:

- Stefan Kohlegger (Evaporation, Bleaching, Drying)
- Stefan Grosswindhager (Paper Quality)
- Kathrin Zörweg (O_2-Delignification, Causticizing)
- Andreas Roither-Voigt (Recovery Boiler, Digesters)
- John Köhler (Steam Networks, Boilers)

Changing perspectives™

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Tieto, ZSPM Manufacturing, Retail and Logistics
andreas.roither-voigt@tieto.com