Energy and Quality oriented modeling and control of REFiners

Wolfgang Birk
Background

- During the MeSTA projekt a pre-study regarding energy usage in a refiner was conducted.
- Initiated by Göran Löfgren.
- The results indicated that further work would be needed and uncertainties needed to be reduced.
- Proposal work continued but no funding was aggregated.
- SCOPE-II funding enabled EQoRef
- Started in March 2012.
Aim and scope

• Improved and more efficient control of refiners (LC & HC)
• Reduced energy consumption and maintained quality

• New methods for analysis and control of refiners
• New proposed work flows

• Demonstration of the results on a real-life refiner

• Work will be limited to one paper mill.

• Focus is NOT on experimental work
Understanding the gap

Source: Karin Ericsson, Entropy based modelling approach to internally interconnected TMP Refining processes.
Understanding the gap (2)

\[ R_P \]

\[ R_0 \]
Understanding the gap (3)

- The are many parameters that affect the behaviour.
- Example temperature profile:
Literature Study about Refining

Patrick Höhn
Luleå Tekniska Universitetet
SCOPE Meeting
9.5.2012
Outline

- Experimental work
  - Pulp flow
  - Measurement techniques
- Modelling
  - Pressure and temperature profile
  - Shear factor
- Patents
Experimental Work – Pulp Flow

- Plug flow in pipes at low flow speeds
- Transition region with less friction
- Turbulent flow at higher speeds

Experimental Work – Pulp Flow

- Paper presented photographic study of a plexiglas model refiner
- Laminar three dimensional flow with three kinds of contributions
  - Primary flow

Experimental Work – Pulp Flow

- Paper presented photographic study of a plexiglas model refiner
- Laminar three dimensional flow with three kinds of contributions
  - Secondary flow

Experimental Work – Pulp Flow

- Paper presented photographic study of a plexiglas model refiner
- Laminar three dimensional flow with three kinds of contributions
  - Tertiary flow

Experimental work – Pulp flow

Experimental work – Pulp flow

### Experimental work – Measurement techniques

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<tr>
<th>Category</th>
<th>Sensors</th>
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<td>CCD cameras</td>
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<tr>
<td>Pressure</td>
<td>Strain gauges, piezoresistive sensors, water manometers</td>
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<td>Shear force</td>
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<td>Temperature</td>
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<td>Plate clearance</td>
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<td>Vibrations</td>
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<tr>
<td>Consistency</td>
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</table>

Modelling – temperature and pressure profiles

- Pressure profile

\[ p(r) = \frac{\rho \cdot \omega^2 \cdot (r^2 - r_1^2)}{2} - \frac{(2 \cdot n + 1) \cdot K \cdot m^2 \cdot r^{(1-n)}}{(1 - n) \cdot (2 \cdot \pi \cdot \rho)^n \cdot b^{(2 \cdot n + 1)}} \cdot \left[ 1 - \left(\frac{r_1}{r}\right)^{(1-n)} \right] \]

- Temperature profile

\[ T(r) = \frac{\dot{m}_g \cdot h_{fg}}{\rho \cdot C_V \cdot \bar{U} \cdot A} - \frac{K \cdot \omega^{(n+1)} \cdot r^{(n+2)}}{(n + 2) \cdot \rho \cdot C_V \cdot \bar{U} \cdot b^{(n+1)}} \cdot \left[ 1 - \left(\frac{r_1}{r}\right)^{(n+2)} \right] \]

Modelling – Shear factor

- Shear factor

\[ \lambda = K \left[ \frac{3n + 1}{n} \right]^n \left[ \frac{8U}{D} \right]^{n-1} \]

- Shear stress

\[ \tau_w = \lambda \left[ \frac{8U}{D} \right] \]


- Procedure and System for Control of a Refiner to improve Energy Efficiency and Pulp Quality
- Spatially distributed sensors in predefined locations
- MPC control scheme
Manipulated variables: $u_1 = (F_p F_D P_{hydr} P_{inlet})^T$

Measured variables: $u_1 = (T_1 C_1 Q_1)^T$

Manipulated variables: $u_1 = (\xi_1 T_1 C_1 Q_1 P_1)^T$

TMP Process
Thank you for your attention
Questions?
Activities

WP-I: Quality oriented refiner modeling
- Energy modeling
- Quality modeling

WP-II: Structure and Performance Criteria
- ProMoVis decision making
- Energy-quality balance optimization
- Constrained structure effects

WP-III: Quality oriented MPC
- Quality oriented control scheme
- Structured quality oriented control scheme

WP-IV: Test & Verifying
WP-V: Result transfer

Toolbox and software environment
# Project plan

## Work package / Task

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<th>2012</th>
<th>2013</th>
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Wolfgang Birk | Control Engineering Group | LTU | 2012-05-08
Experiments and tests

- Preliminary discussion are done and planning is ongoing.
- Mondi will be able to perform the tests both for LC and HC.
- New measurement equipment will be needed (within the gap!)
- Billerud has similar products and the same problem.
- If a secondary plant should be used for tests then Billerud Karlsborg is a good candidate.
- Could be a backup if testing can not be performed at Mondi.
Parameters and measurements

• Quality parameters
  – Distinguish paper quality parameters from production related parameters
  – Example for the latter: Freeness
  – In an optimization scheme those have different characteristics

• Measurements
  – Use available equipment to as large extent as possible
  – Use only devices that are available on the market
  – No sensor development
  – Make use of online measurements to as large extent as possible
Milestones and deliverables

• M1 – Modeling and decision support
  – October 2012
  – SCOPE deliverables: 1 Product (ProMoVis-OS), 1 Service (Control strategy planning), 1 new company started (ProMoVis-OS)

• M2 – EQ Optimization
  – March 2013
  – SCOPE deliverables: 1 Service (EQ optimization = adjusting parameters)

• M3 – Control scheme
  – June 2013
  – SCOPE deliverable: 1 Demonstrator (off-line control scheme)

• M4 – Structured control scheme and tool
  – December 2013
  – SCOPE deliverable: 1 Proof of concept (on-line test of control scheme), 1 Service (control strategy planning refiner)
Relationsship milestones and tasks

- **M1**
  - T1.1 Energy Modeling
  - T2.1 Promovis decision making
  - T4.2 Modeling campaign

- **M2**
  - T1.2 Quality Modeling
  - T2.2 EQ Optimization

- **M3**
  - T3.1 MPC based control scheme

- **M4**
  - T3.2 MPC based structured control scheme
  - T4.3 Control campaign
Comment on T4.1

• T4.1: Experiment and test project planning

• Aim and scope:
  – The results from the project are narrow and need to be broadened
  – More resources needed, both in industry and LTU
  – Such a project should either be funded by industry or an external source
  – Proposal is partially available and under discussion with Mondi

• Dependency:
  – EQoRef is planned such that it does not depend on T4.1
  – An experiment and test project should not start before 2013 and should make use of the results of EQoRef.
ProMoVis Open Source

- EQoRef will make use of ProMoVis.
- The results of PrOSPr (VINNOVA funded project) will be used.

- Promovis will be released under the Apache Open Source license in June 2012.

- Sourceforge site is already created.

- Copyright and IP-rights owner will be a new company that governs the development of ProMoVis
ProMoVis