Calibration and Optimization of a SimulationX Model for the mechanical dewatering process of pulp webs

WOST 2020

Timo Frick  |  2020-06-25
# Introduction

## Voith in numbers

<table>
<thead>
<tr>
<th>In more than</th>
<th>60</th>
<th>19,500</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>countries</td>
<td></td>
<td>employees</td>
<td>markets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R&amp;D ratio</th>
<th>Family-owned since</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.3 %</td>
<td>1867</td>
<td>€4.2 Billion</td>
</tr>
</tbody>
</table>

As of: 2017/18
Paper

Technologies from Voith are used in all sectors of the paper industry. A large proportion of the world’s paper is produced on Voith paper machines.
1. Papermaking Process
2. Press Model
3. Compression Model Calibration
4. Optimization of Press Profile
5. Summary
Papermaking Process
Papermaking Process Overview

Stock Preparation

Approach Flow/ Wet End

Forming section

Press section

Drying section

Sizing/ Coating

Calender

Reeling
Press Model
• High loads and very **short pulse times** make it nearly impossible to reproduce press nip on lab equipment

• **Complex physics** involving structural stress of porous materials, capillary pressure and multiphase flow make it hardly accessible for microscopic simulations

• **Process simulations** using effective material parameters help in understanding interplay of elastic and plastic **deformation** and **dewatering**
Press Model
Functional layers

- Capillary pressure model
- Porous media model
- Compression model
- Phase transition model
- Heat driven moisture change

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Press Model
Compression Model

Terzaghi’s principle:
Porous material subjected to stress is opposed by fluid pressure of pores

Stress on porous material causes deformation and movement of fibers

Mechanical compression model with effective physical parameters

$\sigma$: total (external) stress, $\sigma'$: effective stress on porous material, $u$: pore pressure
Compression Model Calibration
Compression Model Calibration

Calibration procedure

Dynamic compression trials of wet fiber mat

Numerical **minimization** of the difference between trial deformation and simulated deformation
Compression Model Calibration
Parallel calibration

- Calibration procedure can be extended to multiple curves in parallel:
  \[
  \min \left\{ \sum \| d(\text{ref}_k, \text{sim}_k) \| \right\}
  \]

- Using miscellaneous curves for calibration ensures a universally valid compression model.
Press Profile Optimization
Press Profile Optimization
Approach

- Parametrization of pressure profile using non-equidistant distributed grid points

- Numerical optimization of pressure profile:
  \[ \max \{DSC(p_1, p_2, \ldots, p_n) : \int p(x) dx = \text{const} \} \]

Dry solid content
  Quantifies the efficiency of the dewatering process

Line load
  Quantifies the applied load on the paper mat

**Schematic drawing**

- Parametrization of a pressure profile –
  
- Height [mm]
  - Stress [MPa]
  
- Time [s]
Press Profile Optimization
Implementation

- Lineload restriction can be realized by:
  - $\text{Lineload}_{ref} \geq \text{Lineload}$ as boundary condition
  - $\min \{(\text{Lineload}_{ref} - \text{Lineload})^2\}$ as additional objective
  - Using MOP as surrogated model speeds up the optimization process with sufficient accuracy.
Summary
Using optimization capabilities of OptiSLang allows calibration of highly nonlinear models.

By parametrizing and optimizing the press profile curve (input signal) the dryness after press (output) can virtually significantly increased.

Embedding OptiSLang in simulation workflows boosts modelling as well as application projects.
Thank you!