Control Application of the Week!

Paper Machine Control: Machine-Direction Control
Paper Machine
Figure 1.1 The principle of paper production is simple. The water is separated from the original stock which is smoothened out to a thin and endless paper sheet. By adding different types of fillers the paper surface obtains different properties. Typical values of moisture content are indicated. By courtesy of Skogsindustrierna.
Headbox and Table

- Pulp stock is extruded on to a wire screen up to 11 metres wide and may travel faster than 100km/h.

Initially, the pulp stock is composed of about 99.5% water and 0.5% fibres.
Dryer Section

• The pressed sheet is then dried to moisture specifications.

The paper machine pictured is 200 m long and the paper sheet travels over 400 m.
Dry End

- The finished paper sheet is wound up on the reel.

The moisture content at the dry end is about 5%. It began as pulp stock composed of about 99.5%
Scanning Gauges

Paper properties are measured by a sensor traversing the full sheet width.

Basis weight sensor

Scanning frame
Scanning Sensor
Steam and Condensate System
Variables Affecting the Drying Process

- Moisture
- Dry weight
- Production speed
- Layer distribution
- Formation
- Bulk
- Web temperature
- Retention
- Filler
- Refining
- Freeness

Steam pressure
Process air
Leakage air

Condition of fabrics
Web tension
Condensate distribution
Tuning of controllers

Dryer section

Blow through steam
Condensate flow
Exhaust air
Moisture Control Loop

- Cascade configuration
- PI controller in inner loop
- Dahlin controller in outer loop
Steam Pressure Dynamics

\[ G_{IPZ}(s) = k_v \frac{(1 + sT_1)}{s(1 + sT_2)} e^{-sL} \quad T_1 > T_2. \]  

(3.1)
Steam Pressure Control Before Retuning
Steamp Pressure Dynamics

Figure 5: Measured and estimated model response for 5th dryer section steam pressure

The estimated model for the 5th dryer section is:

\[ G(s) = \frac{0.0062(1+220s)}{s(1+85s)} e^{-s} \]
Steam Pressure Control After Retuning

5th Dryer Section Steam Pressure Setpoint and Measured Value

6th Dryer Top Section Steam Pressure Setpoint and Measured Value
Weight-Moisture Interactions
Weight-Moisture Interactions
Interactions

a) Steam pressure

[Diagram showing a process flow with steps:
- Stock flow
- Drying process
  - Output: Moisture
- Paper sheet process
  - Output: Total weight]
Interactions

b) Steam pressure

Stock flow

Drying process

Moisture

Paper sheet process

Dry weight
Effect of Stock Flow on Moisture
Decoupling Moisture from the Stock Flow

Consider the moisture process

\[ y = G_{11}u_1 + G_{21}u_2 \]

where \( u_1 \) and \( u_2 \) are respectively the steam pressure setpoint and the stock flow while \( y \) is the size press moisture.

Ignoring for now the moisture feedback if we introduce a decoupler \( D \) such that \( u_1 = Du_2 \) it is easy to see that \( D \) must be such that

\[ 0 = G_{11}Du_2 + G_{21}u_2 \]

or

\[ D = -\frac{G_{21}}{G_{11}} \]

With \( G_{11} = \frac{-0.059e^{-38s}}{1+0.001s} \) and \( G_{21} = \frac{0.023e^{-57s}}{1+62s} \)

we find

\[ D = \frac{0.4e^{-19s}}{1+62s} \]