Consistency and Freeness
Pulp Consistency

• Definition
• Ranges
• On-line measurement
• Control principles
• Reference: “Accurate Consistency: a handbook on accurate consistency”
• Consistency is the percent of oven dry mass in the pulp

\[
\text{Consistency} = \frac{\text{Dry weight of sample}}{\text{Total weight of sample}} \times 100\%
\]

• Accurate consistency control vital to uniform quality and production

• Consistency affects the efficiency and productivity all most all unit operations
  - Many have narrow operation range, eg, screens plug at too high consistency
  - Many have narrow range of efficient operation, eg, cleaners are not effective above 1.5% consistency.
## Consistency ranges

<table>
<thead>
<tr>
<th>Consistency Ranges</th>
<th>Consistency</th>
<th>Processes and Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-40%</td>
<td>High Consistency</td>
<td>Mechanical pulping, reject refining, bleaching, storage</td>
</tr>
<tr>
<td>5-12%</td>
<td>Medium Consistency</td>
<td>Cooking, bleaching, storage, repulping</td>
</tr>
<tr>
<td>1-5%</td>
<td>Low Consistency</td>
<td>Stock prep, cleaning, screening, beating blending</td>
</tr>
<tr>
<td>0.1-1.0%</td>
<td>Very Low Consistency</td>
<td>Headbox, whitewater flotation deinking</td>
</tr>
<tr>
<td>0.01-0.1%</td>
<td>Ultra Low Consistency</td>
<td>Clarifier, clear white water</td>
</tr>
</tbody>
</table>
Consistency Measurement

• Shear Force
  – Most widely used in the industry
  – Blade (passive)
    • A blade is placed in the pulp flow.
    • Force on the blade is dependent on network strength
      and fluid velocity
  – Rotating (active)
    • More accurate and expensive
    • Effective fluid velocity is more controlled
Blade consistency transmitters

- Practical consistency range 0.8 to 16%, velocity range 0.3 to 1.4 m/s
- Different consistencies give different drag relations
- Network strength dependent on
  - Pulp type
  - Fibre length, filler and fines content.
  - Pulp processing, refining ...
  - Chemical addition, ph
Rotating consistency transmitters

- Very common, more reliable and expensive
- Consistency range > 0.8%, velocity range 0.1 to 1.4 m/s
- Rotor speed is large with respect to flow velocity therefore approximately independent of flow
- Dependent on factors affecting network strength
Other methods

• Optical
  – Light scattering / absorption (1980’s)
  – Transmission or reflection types
  – Hope to get accurate low consistency measurements. Not very accurate or reliable.
  – Dependent on total surface of fibres
    • Varies with refining, fines content, filler etc.
Other methods

- Nuclear, gamma gauge
  - Detect density of fluid
    - In theory it is possible to calculate consistency from the density difference between water and cellulose fibres.
    - Cellulose is approx 1.5 g/ml
  - Very sensitive to high Z (Nuclear mass) material. Fillers i.e. clay, CaCO3, TiO
  - Black liquor content
Other methods

• Microwave
  – Measures wave speed through fluid
  – Calculate the dielectric constant .. Get water content.
  – Range 1% to 25%
  – Depends on
    • Air content in water
    • Conductivity, liquor and bleaching carryover
    • Poorly mixed pulp
    • Deposits on sensor
Other methods

• Pressure drop across a length of pipe
• Ultrasound
• Video imaging …
• For greater 30% consistency
  – NIR
  – Dielectric measurement of water
  – No really good method to measure these high consistencies
Laboratory Measurements

- Oven dry for
- Sampling: Difficult to get representative sample
  - Varies with time so you need a sampling time long enough to get average
  - Varies spatially in flow
    - Plug in the centre of the pipe, water annulus at wall, therefore an artificially low sample consistency if tapped off the wall
    - Need to ensure a proper sampling tap placement.
  - Dewaters easily at valve. Need ball valve or special consistency valve
Consistency control
Blow tank consistency control

\[ C_s = 8-12\% \]

Blow tank

\[ C_s = 3-4\% \]

Dilution header

Coarse

Fine

MEK-2308

CRC

CT

FT

FIC

R/R
Staged consistency control
Canadian Standard Freeness

- Ability of water to drain through the pulp
- Measured as volume of water draining through side-orifice (units of mL)
- Function of surface area, coarseness, fibrillation, flexibility, fines content, others …