Introduction

- Pulp screens are essential for contaminant removal and fractionation
- Cylinder and rotor are the key performance components
What we cover today

- Develop a mathematical model of a single screen
- Calculate the volumetric, mass and contaminant flow through a screening system and a system of screens
- Power consumption of a screen rotor
- Development of a novel foil rotor

Objectives of Pulp Screening

- Contaminant removal
- Fibre fractionation
- Deflocculation
- Protection
Contaminants

- Shives are unpulped pieces of wood
- Most common contaminant
- Weaken paper, leads to machine breaks
- Source of visible dirt
- Rougher surface
- Returned to digester or sent to reject refiner

Contaminants

- Sclereids are inner bark cell clusters
  - dense highly lignified
  - show up as windows in calendered sheets
- Strings
  - fibre bundles produced in the process
  - similar problems as shives
Contaminants

- Plastic
  - cause streaks and cuts during coating
  - typical polyethylene, SG < 1.0

- Fibre fractionation
  - remove coarse and long fibres for further treatment

TMP Screening and Cleaning System
Pressure Screen Equipment

Parts of a Pressure Screen

- Pulp and contaminants enter through feed port
- Fibres pass through screen plate, shives retained by screen plate
- Rotor produces pressure pulses to back flushes the apertures
- Clean pulp exits through accept
- Contaminants exit via reject port
- Dilution counters reject thickening
- Rock trap
Cylinder Types

- **Holed cylinders**
  - 1.0-2.5 mm diameter holes
  - 15-25% open area
  - probability screens
  - durable, 20 year old technology

- **Slotted cylinders**
  - 0.1 mm to 0.5 mm wide slots
  - 3-5% open area
  - barrier/probability screens
  - always contoured
  - **Milled**
    - Can’t make below 0.2 mm wide
  - **Wedge wire** (Welded wires)
  - **MacroFlow** (constructed)

Slotted Screen Plate Manufacturing

- **Wire cylinders**
  - Continuous slots increase open area
  - Higher capacity (shape and open area)
  - Most expensive
  - Early plates were weaker construction, susceptible to fatigue failure and had questionable tolerance … no longer true.
Screen Plate Contours

- Contours
  - protrusion on feed side of cylinder
  - increase turbulence
  - redirect flow into aperture
  - increased barrier screening
  - reduced probability of screening fractionation and reject thickening

Wire shapes

AFT has a range of Profile™ selections to suit a range of conditions.

Deeper contours tend to provide better capacities and reduced thickening - but at the expense of efficiency.
Contoured Screen Surface

- CFD simulation of flow over surface
- Contour height
  - Decreases Thickening
  - Decreases Efficiency
  - Increases Capacity

Slot tolerance

Slot tolerance is critical to contaminant removal and screen capacity.
Slot tolerance specifications:
90% of slots are within $\pm 0.001$" of average width
100% of slots are within $\pm 0.002$" of average width
Average of slot widths are within $\pm 0.0008$" of the nominal slot width.

Rotors

- Produce pressure pulses to backflush pulp accumulations from the screen plate apertures
- Induces high tangential fluid velocity at screen surface
- Can be foils or bumps … many types available…
Suction / cleansing action of rotor

What controls the passage of fibres through the screen plate?
Barrier Screening

Probability Screening
Turning Effect

Mathematical Analysis of Screens and Screening Systems
Pressure Screen Analysis

- Develop a mathematical description of screens and screening systems
- Allows us to engineer the process
- How?
  - Quantify probability of passage by a Passage ratio
  - Derive performance equation for consistency, contaminant efficiency and fractionation in terms of passage ratio and volumetric reject ratio
  - Derive equation for passage ratio in terms of fibre length, slot velocity and slot width
  - Calculate efficiency of screening system
- Introduce fractionation simulation and optimization as a pulp processing design tool

Definitions for a single screen

- Volumetric reject ratio
  \[ R_v = \frac{Q_{\text{reject}}}{Q_{\text{feed}}} \]
- Mass reject ratio
  \[ R_m = \frac{C_{\text{reject}} Q_{\text{reject}}}{(C_{\text{feed}} Q_{\text{feed}})} \]
- Reject thickening factor
  \[ T = \frac{C_{\text{reject}}}{C_{\text{feed}}} \]
- Shive removal efficiency
  \[ E_s = \frac{S_{\text{reject}} Q_{\text{reject}}}{(S_{\text{feed}} Q_{\text{feed}})} \]
- Long fibre removal efficiency

Q: Volumetric flow rate
C: Consistency
S: Concentration of shives
**Passage Ratio**

- Quantifies the ability of fibres to pass through a single screen aperture

\[ P = \frac{C_S}{C_U} \]

**Flow Model in Screening zone**

- Assume:
  - passage ratio constant
  - no axial mixing (plug flow)
  - perfect radial mixing

\[ QC = CP_p \, dQ + (Q-dQ)(C-dC) \]
$T = R_v^{p-1}$
Efficiency of a single screen

Efficiency: Barrier and Probability

[Graphs showing efficiency as a function of mass reject ratio for different barrier probabilities]
What factors affect passage ratio?

- Aperture type (holes or slots)
- Size of aperture
- Fibre length / contaminant size
- Fluid velocity through aperture
- Rotor tip velocity
- Contour type
- Rotor type
- ?

Which ones are the most important?

- Fibre length, L
- Slot width, W
- Aperture Velocity, \( V_s \)
- Rotor speed, \( V_t \)
- Dimensional analysis might suggest that
Penetration number analysis:
System efficiency - Analysis
System efficiency - Analysis

Power requirements

- How much power is required?
- What are the key variables?
Dimensional analysis

- Power Coefficient,
  \[ C_p = \frac{P}{\rho \omega^3 D^5} = \frac{P}{\rho V_r^3 D^5} \]
- Reynolds Number,
  \[ Re = \frac{\rho \omega D^3}{\mu_a} = \frac{\rho V_r D}{\mu_a} \]
- Capacity coefficient,
  \[ C_q = \frac{Q_r}{\omega D^2} = \frac{Q_r}{V_r D^2} \]
- Reject Ratio, \( R_v = \frac{Q_r}{Q_f} \)

\[ \frac{P}{\rho v_t^3 D^2} = fn(Re, C_q, R_v) \]

Experimental results

- 3 different screen sizes
- Dimensional form

![Graph showing power vs. tip speed for three different screen sizes]
Experimental results

- Non Dimensional

Effect of element geometry

[Diagram showing different element geometries and their corresponding power output against tip speed]
Effect of element geometry (non Dim)

Effect of Feed Flow Rate
Power conclusions

1. \( P \propto \rho V_t^3 D^2 \)
2. \( P \propto Q_f \)
   - Depends on element shape
3. Little dependence on \( R_v \)
Computational Fluid Dynamics

- The foil shape was designed using Computational Fluid Dynamics (CFD)
- Divide domain into fine grid
- Solve fundamental equations for pressure, velocity and turbulence
- Obtain theoretical calculations for flow and pressure on the cylinder
- Examine large number of design variables (shape, angle, etc.)

High Performance Rotor Design

- Rotors generate pulsations to clear screen cylinder apertures
- Optimal pulsations ensure high efficiency, capacity and runnability
- There are more than 200 screens in the province
- 200 HP motors
- Consumes ~ 180 GW h / yr
CFD Results

- Optimal pulse for 5 Deg angle of attack:
  - Strong negative pulse
  - No positive pulse

\[ C_p = \frac{P}{\frac{1}{2} \rho V_t^2} \]
Prototype Pilot Trials

- Experimental conditions:
  - Ahlstrom F1 Screen
  - Cylinder: 0.1mm MF1232
  - Rotors:
    - Prototype EP (60 mm Foil)
    - Prototype EP (130 mm Foil)
    - Gladiator HC (GHC – Solid core)
    - Andritz VF
  - De-ink market pulp
  - 1.4% consistency

Pilot Trial Results
Pilot Trial Results

Current BC Mill Trials

- BC Hydro / Canfor / AFT demonstration project to conduct 2 mill trials
  - Northwood: softwood kraft mill
    - GHC solid core rotor
    - Replace conventional “Stingray” rotor
  - TMP mill:
    - EP foil rotor
    - Jan. 2006
Canfor-Northwood SW Kraft Trial

Graph 1: 
- **Tip Speed (m/s)** range: 18 to 30
- **Power (kW)** range: 0 to 140
- **52% Energy Savings**

Graph 2: 
- **Slot Velocity (m/s)** range: 2.0 to 3.4
- **Debris Removal Efficiency (%)** range: 50 to 100
- GHC (24 m/s) and Stingray (29 m/s) performance comparison
Conclusions

- Two new low energy rotors have been developed
- Performance has been demonstrated in computational, laboratory, pilot and mill trials
- GHC - Solid core
  - 52% energy savings
  - Maintained high efficiency and runnability
- EP – Foil rotor
  - Potential for 80% energy savings
  - Increased efficiency and runnability

The end