Best milling practices in feeding, extraction and power consumption

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Overview of presentation

- Three topics
  - Feeding
  - Extraction
  - Power consumption
- Focus on individual milling units
  - Extraction in particular is also considerably affected by cane preparation and added water rate

Feeding

Feeding

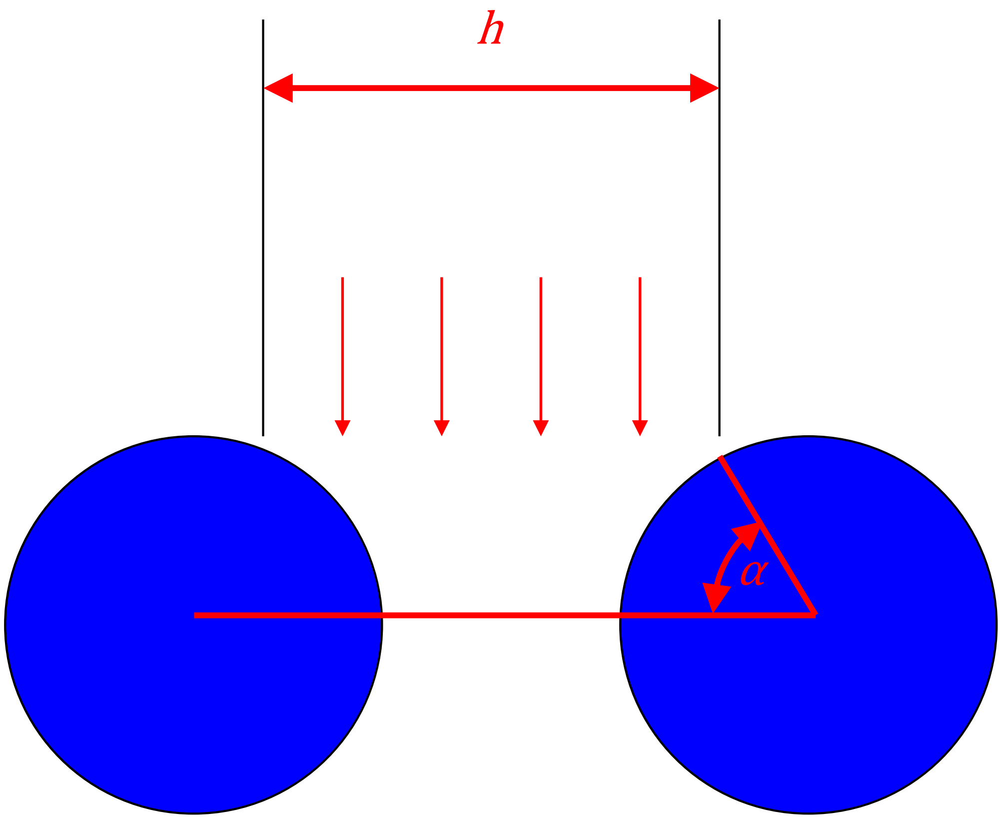
- Definition
  - The cane or cane fibre rate that can be achieved at a particular mill speed
- Associated with the capacity of the mill

Basis for feeding theory

- Based on two-roll mill
- Compaction (γ) at Donnelly chute exit:

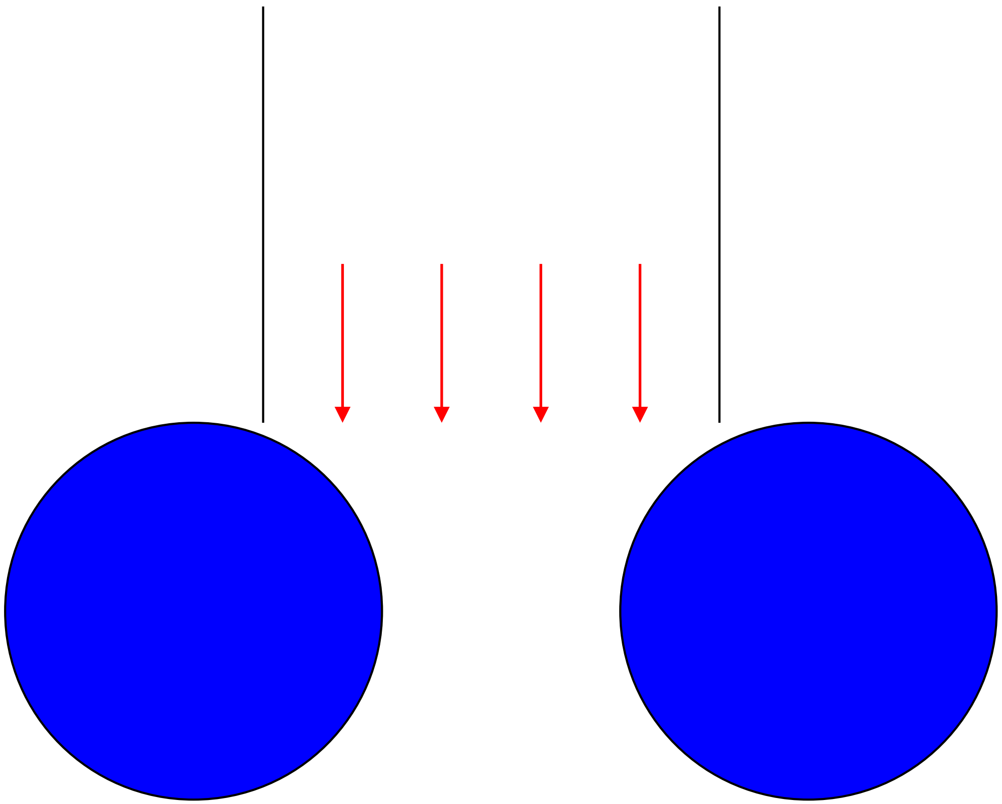
$$\gamma = \frac{Q_f}{LhS\cos\alpha}$$

- Q_f Cane fibre rate
- L Roll length
- h Chute setting
- S Roll surface speed
- α Contact angle



Compaction at Donnelly chute exit

- Compaction at chute exit not affected by mill settings
- Function only of conditions in chute
- Essentially constant year to year



Predicting mill speed

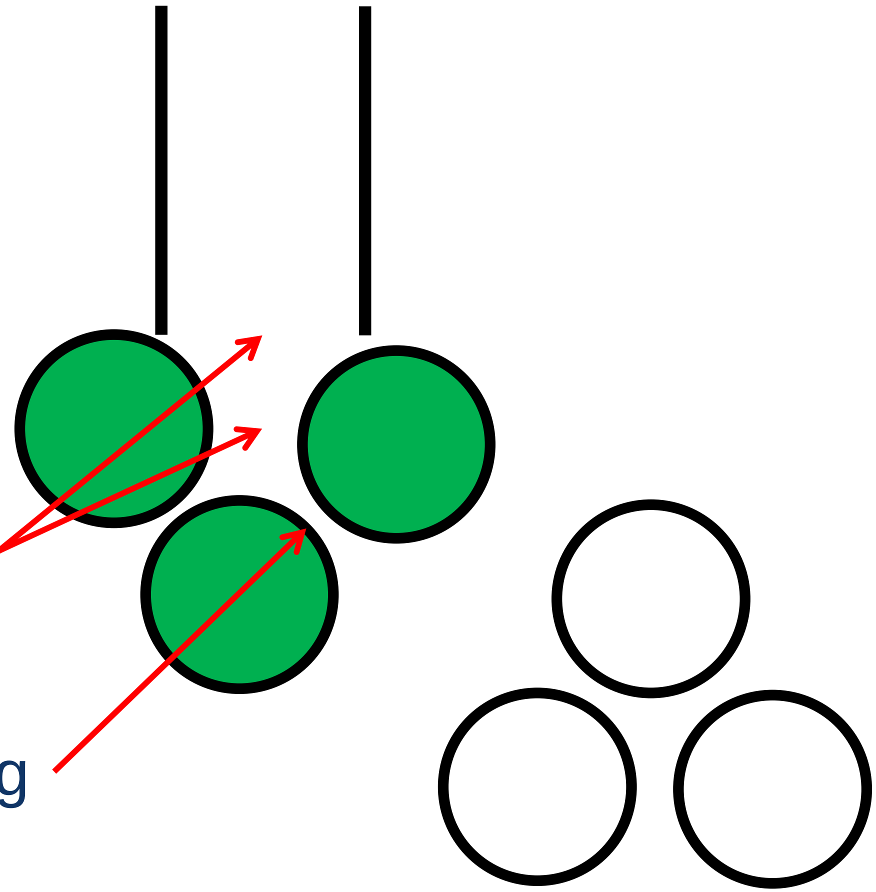
- Assumption of constant compaction at Donnelly chute exit can be used to predict mill speed
- Rearranging the compaction equation:

$$\gamma = \frac{Q_f}{LhS\cos\alpha} \quad \Rightarrow \quad S = \frac{Q_f}{\gamma Lh\cos\alpha}$$

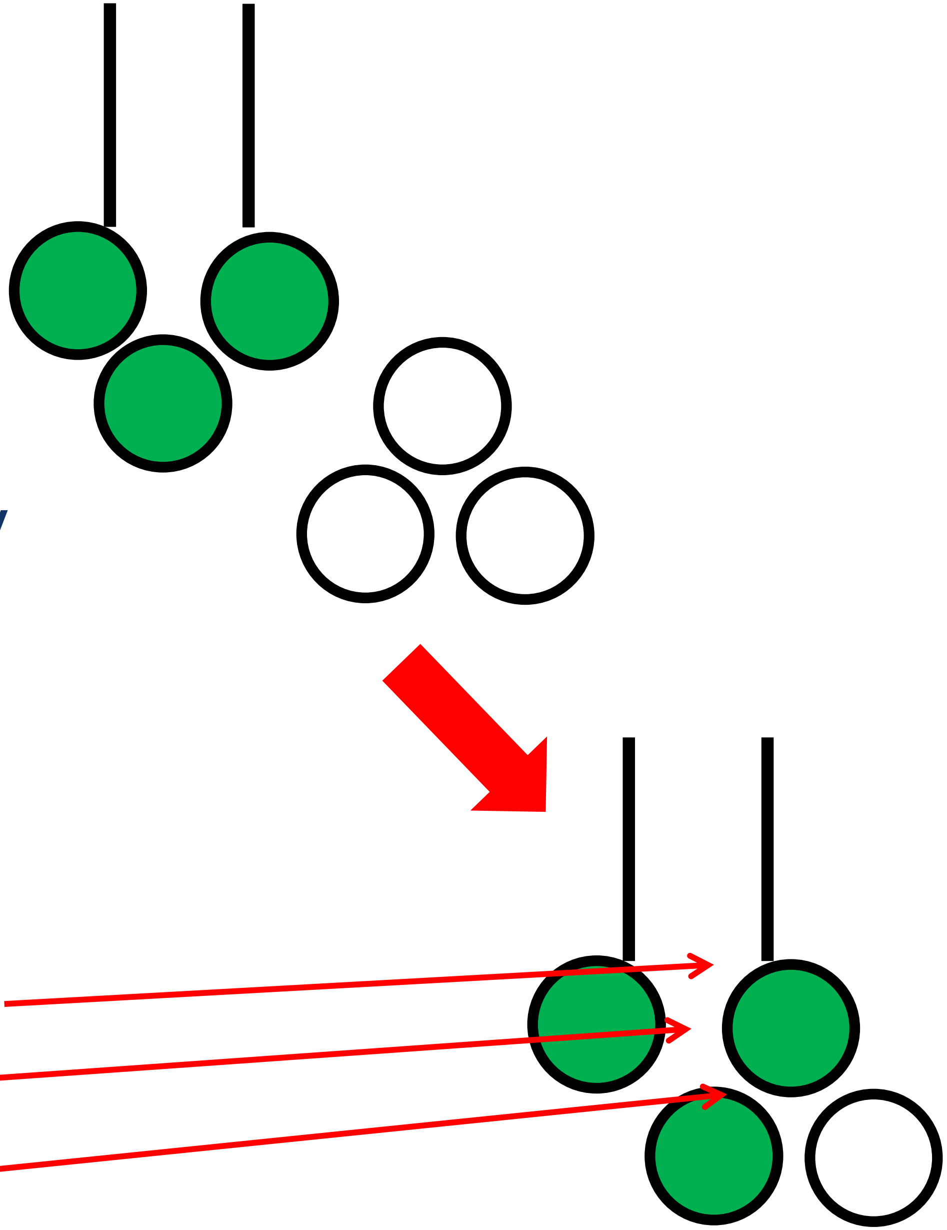
  - Compaction (γ) from previous performance
  - Roll length (L), chute setting (h) and contact angle (α) from mill geometry
  - Fibre rate (Q_f) selected

Application of the feeding theory concept

- As originally conceived, the theory was applied to the pressure feeder
- Theory indicates that mill speed is affected by:
  - Donnelly chute exit setting
  - Underfeed setting
  - Pressure feeder work opening



Application to four-roll mill



- Pressure feeder geometry very similar to first three rolls in four-roll mill
- Theory indicates that mill speed is affected by:
  - Donnelly chute exit setting
  - Underfeed setting
  - Feed work opening

Implications

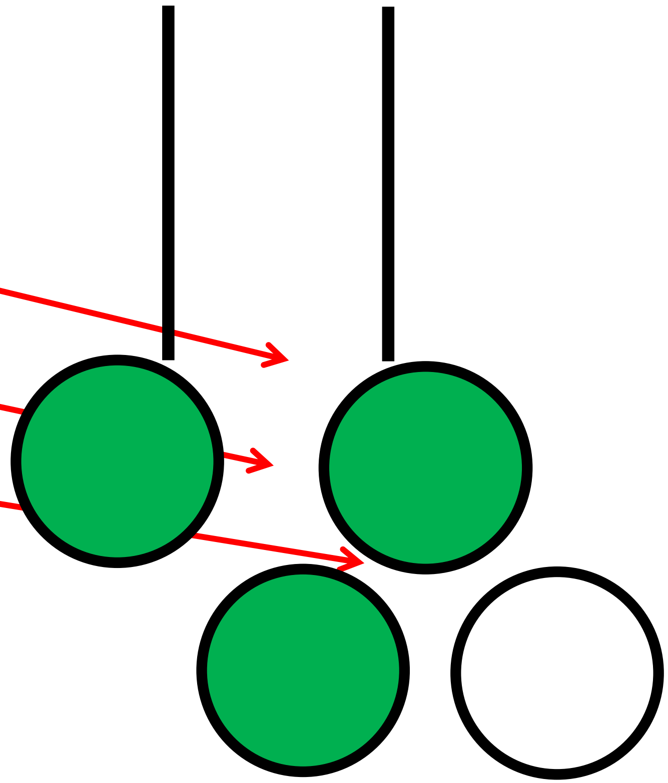
- Choice of settings will affect mill speed
- If the mill is operating near the middle of its speed range, there are no consequences
- If the mill is operating near the top or bottom of its speed range, chute height cannot be properly maintained
- Feeding theory can be used to adjust settings so mill operates in a better speed range

Best practices in feeding

- Setting selection
- Roll surface grip and drainage

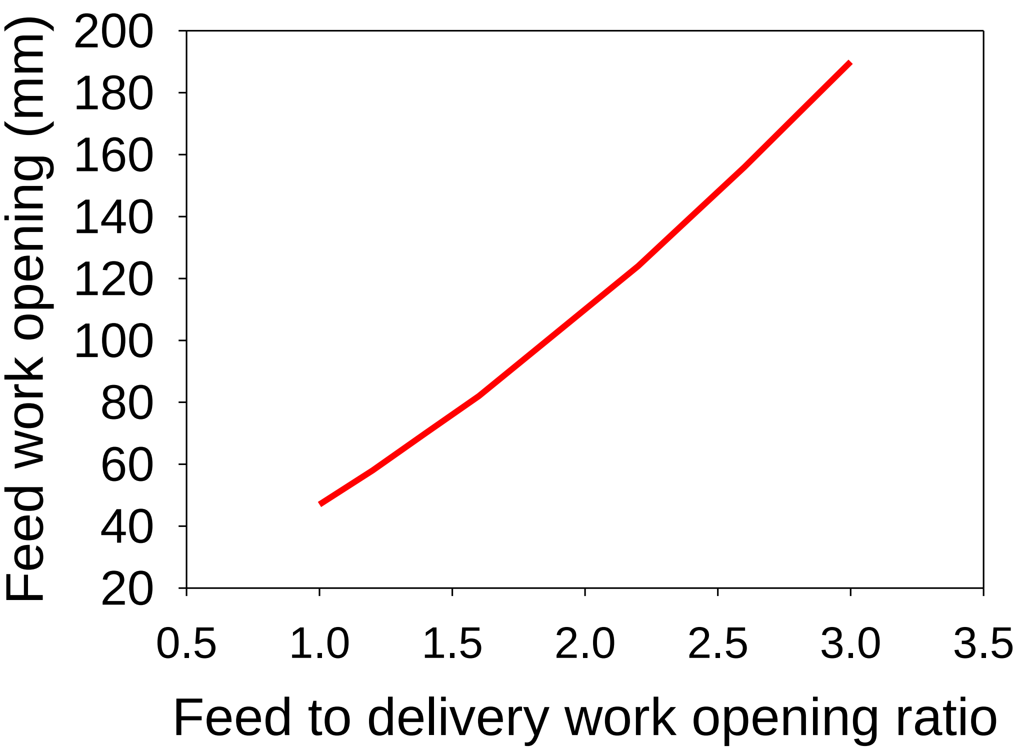
Setting selection

- Choice of settings affects speed:
  - Donnelly chute exit
  - Underfeed nip
  - Feed nip
- Case study for a dewatering mill at Sezela (South Africa) reported SASTA 2014



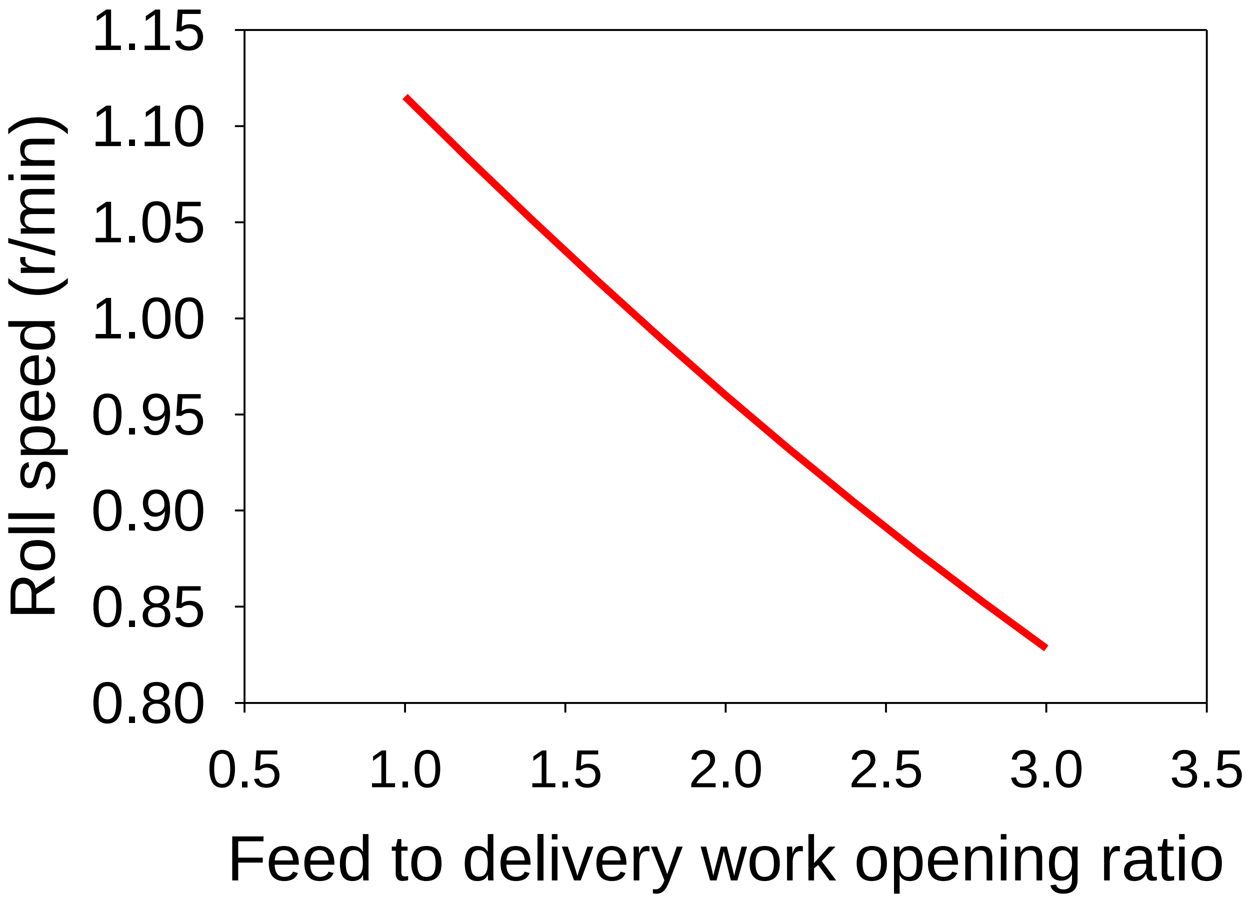
Effect of mill ratio on feed work opening

- Mill ratio is ratio of work openings between feed and delivery nips
- Typically used to calculate feed setting
- As set:
  - Work opening ratio 1.8
  - Feed work opening 93 mm



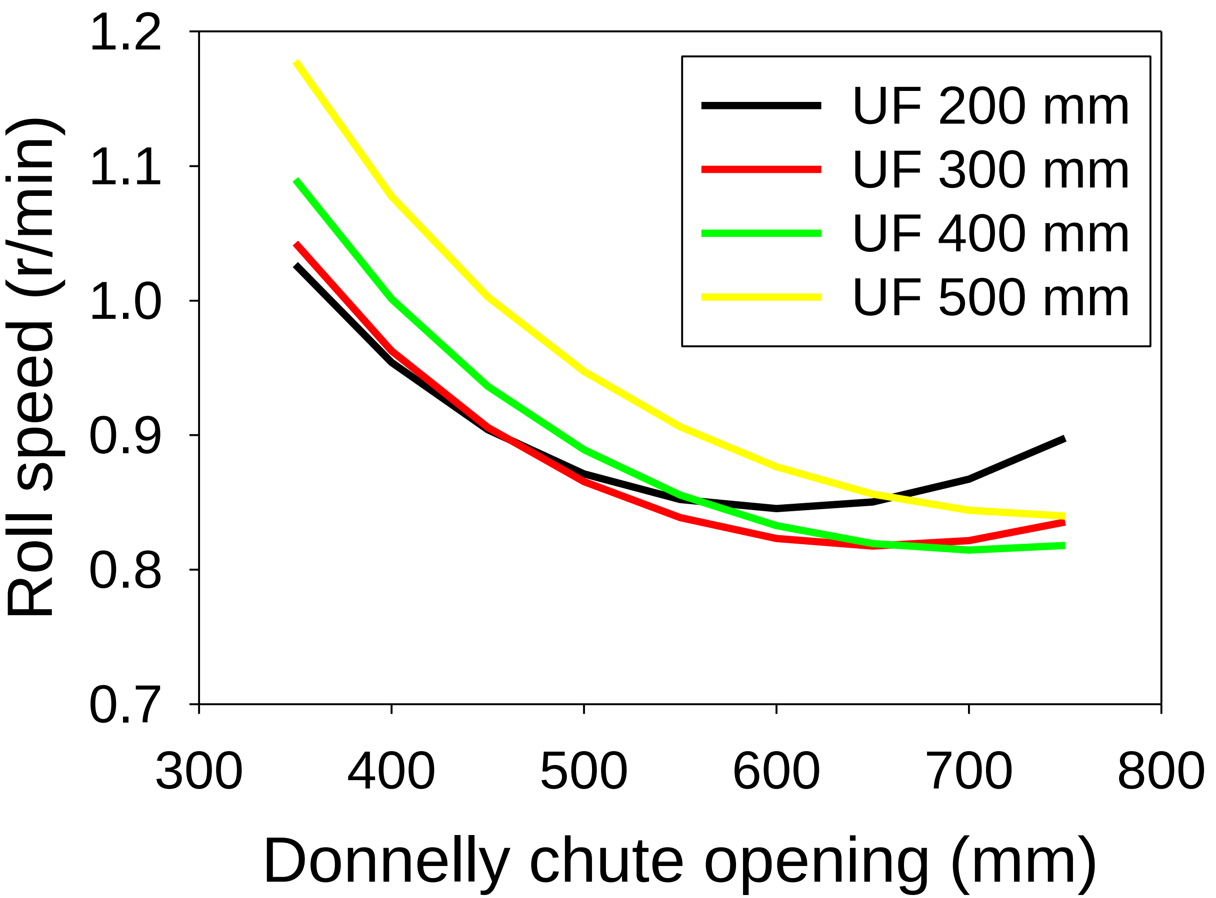
Effect of mill ratio on roll speed

- As set:
  - Work opening ratio 1.8
  - Speed 1.0 r/min



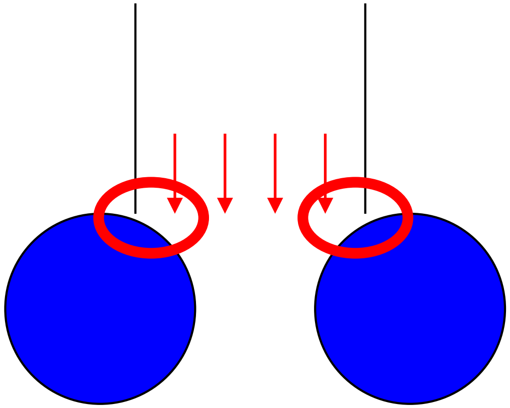
Effect of underfeed and Donnelly chute exit opening

- Feed work opening 93 mm
- As set:
  - UF 216 mm
  - Donnelly 369 mm



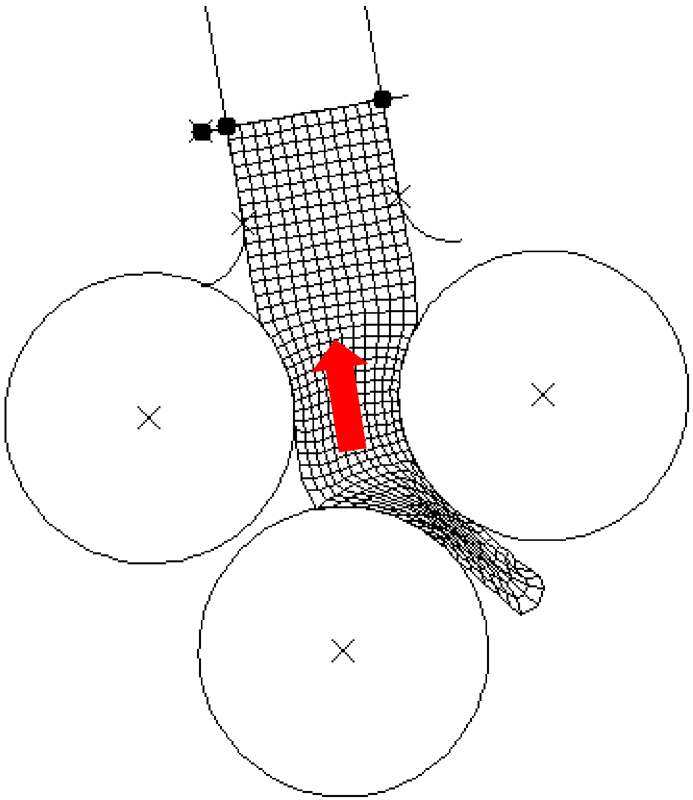
Roll surface grip

- Feeding dependent on rolls gripping the bagasse
- Picots seem a good way of doing that



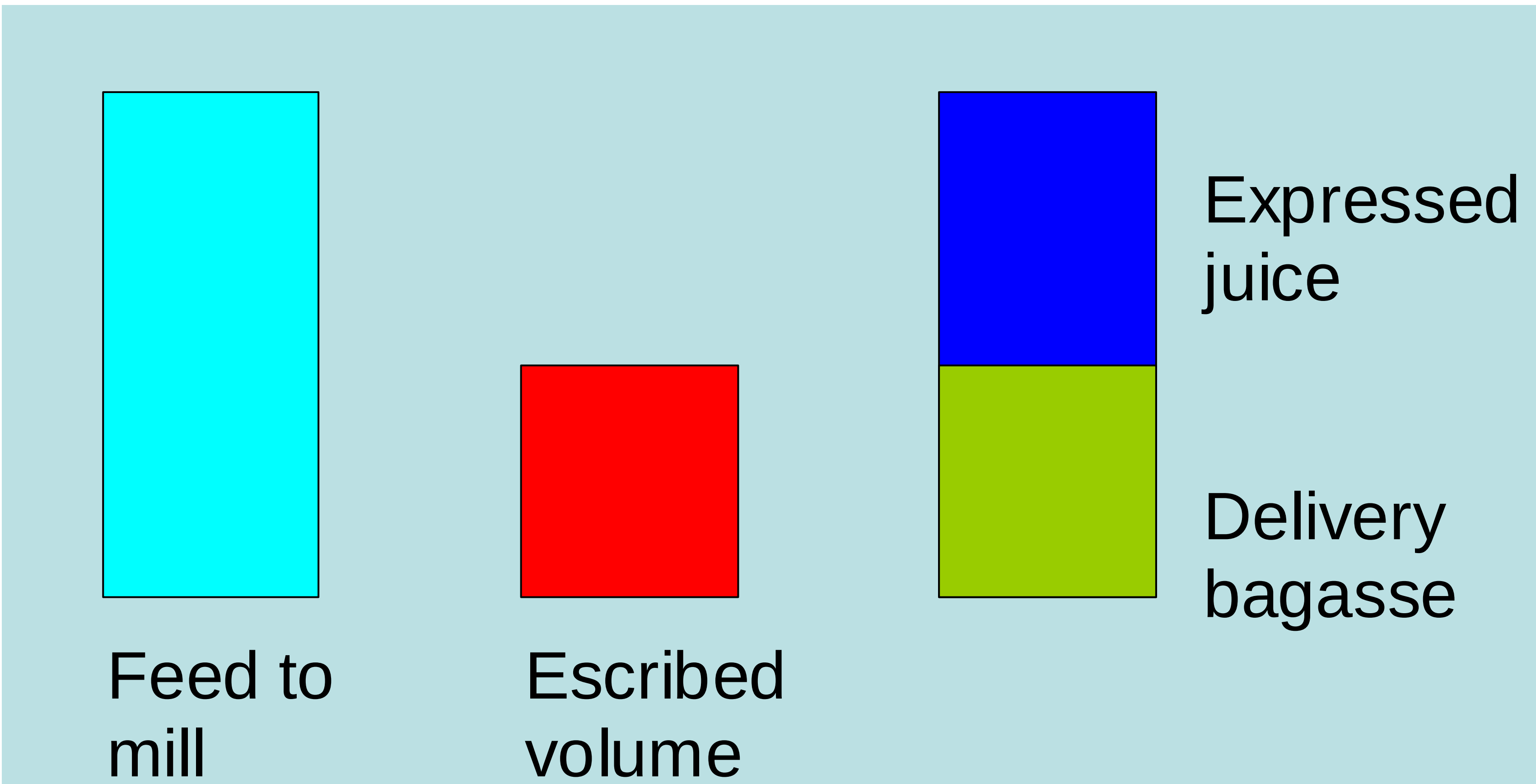
Roll surface drainage

- If juice cannot easily drain away from the roll surface, it has to force its way back in the direction of feeding
- Bad for feeding
- Solutions
  - Messchaert grooves
  - Lotus rolls



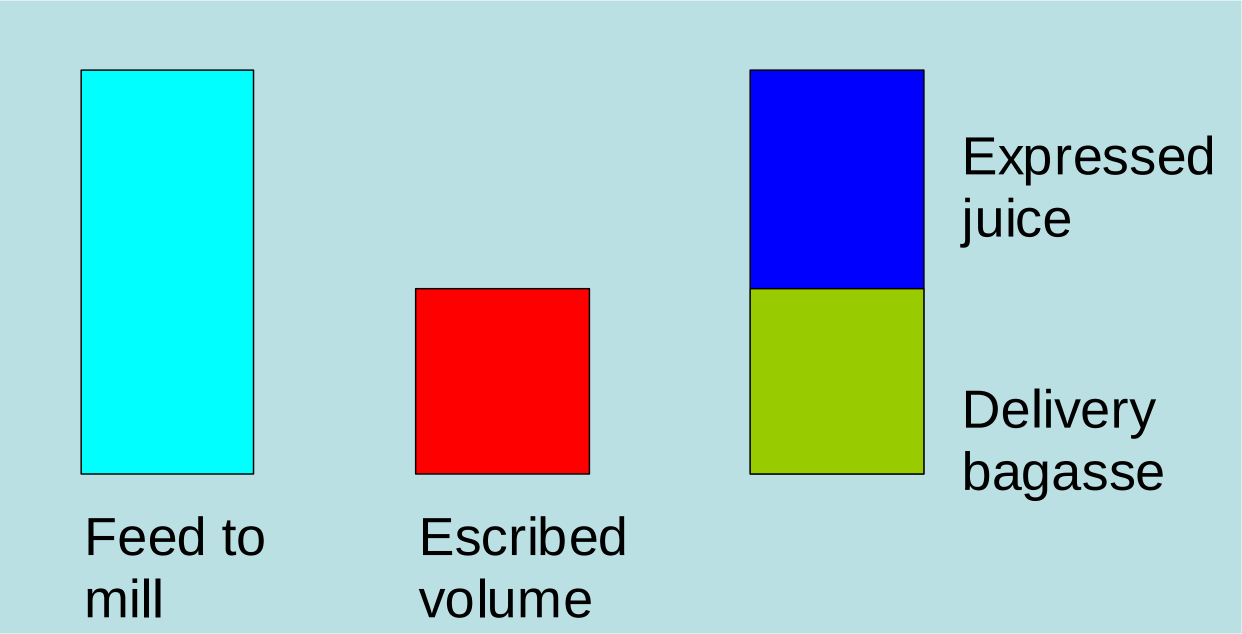
Extraction

Volumetric theory of juice extraction



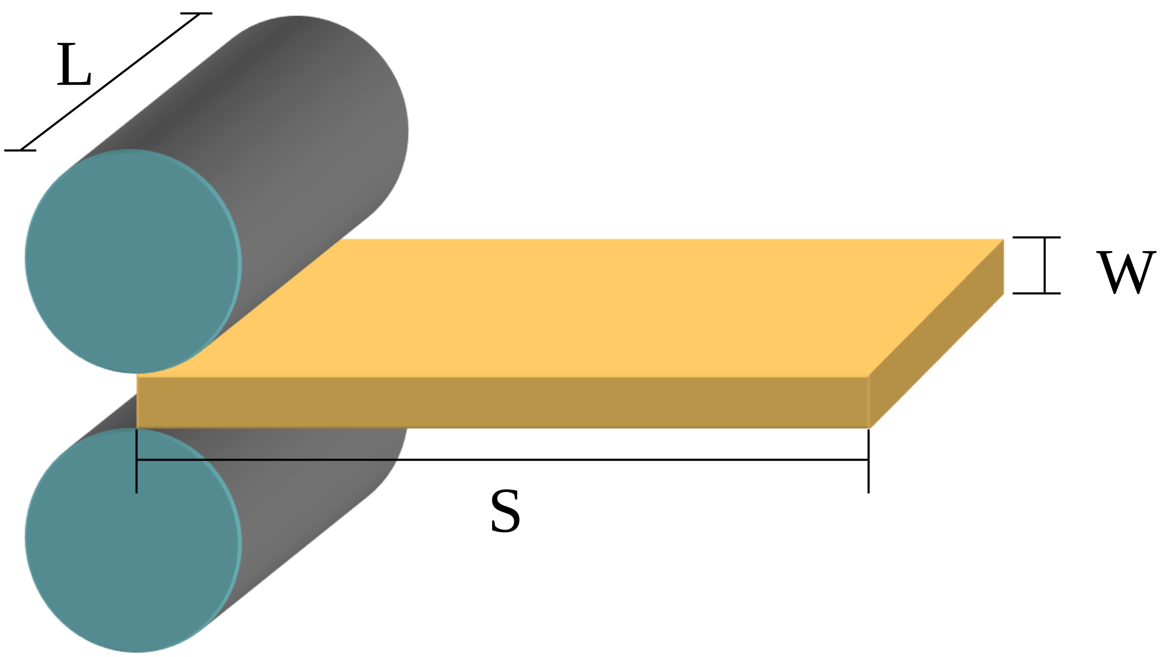
Increasing extraction approach 1

- Volumetric theory shows that reducing escribed volume will reduce volume of delivery bagasse
  - Hence increase extraction



Escribed volume (V_E)

- Escribed volume of final nip influences extraction
- $V_E = LWS$
- L = roll length
- W = work opening
- S = surface speed



Influencing escribed volume

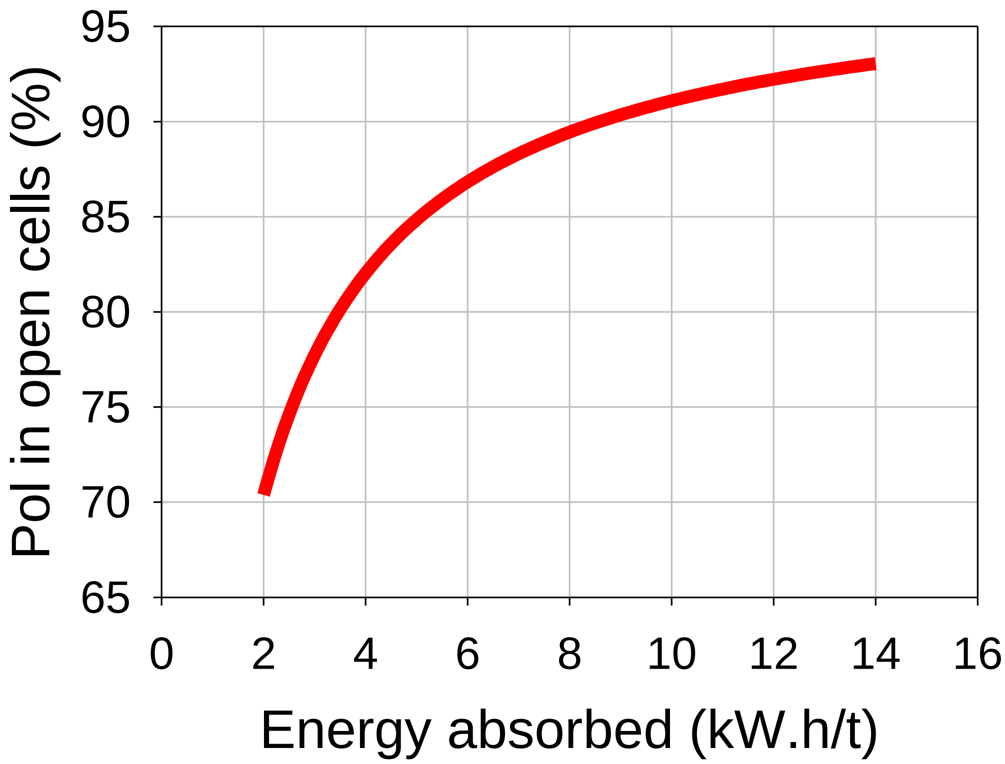
- Option 1: change top roll hydraulic pressure
- Increases delivery nip compaction
- If increasing pressure, need to ensure top roll shaft has sufficient strength

Influencing escribed volume

- Option 2: enable higher delivery nip compaction at the same hydraulic pressure
  - Better preparation
  - Softer bagasse

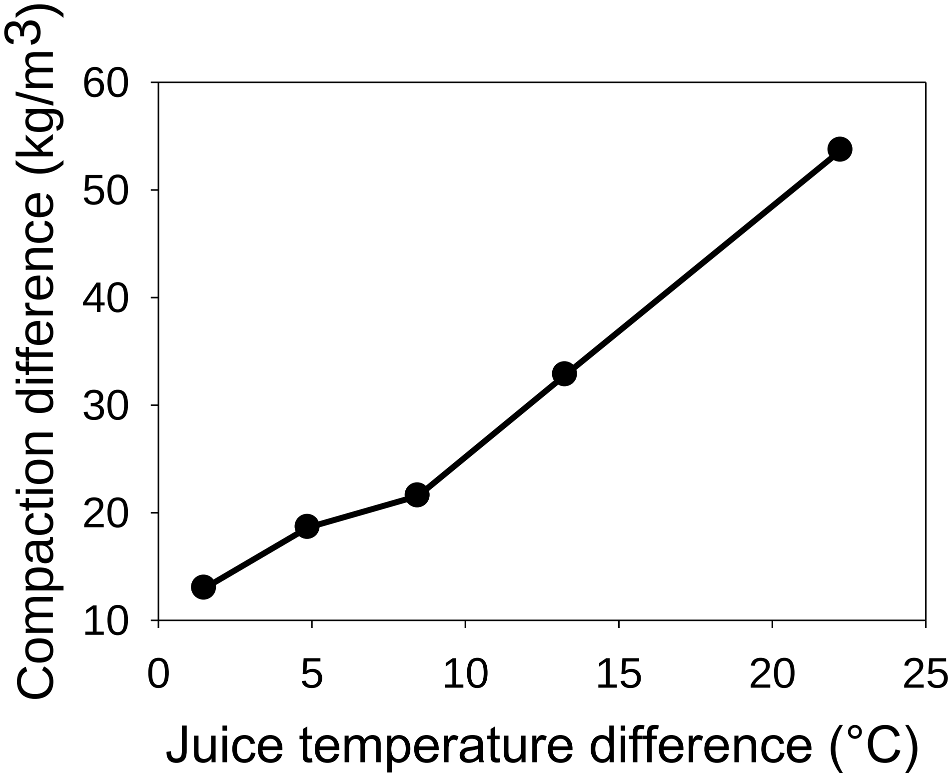
How to change bagasse preparation?

- Change cane preparation
  - Change power consumption
- Change preparation in mills
  - Increase hydraulic pressure in earlier mills

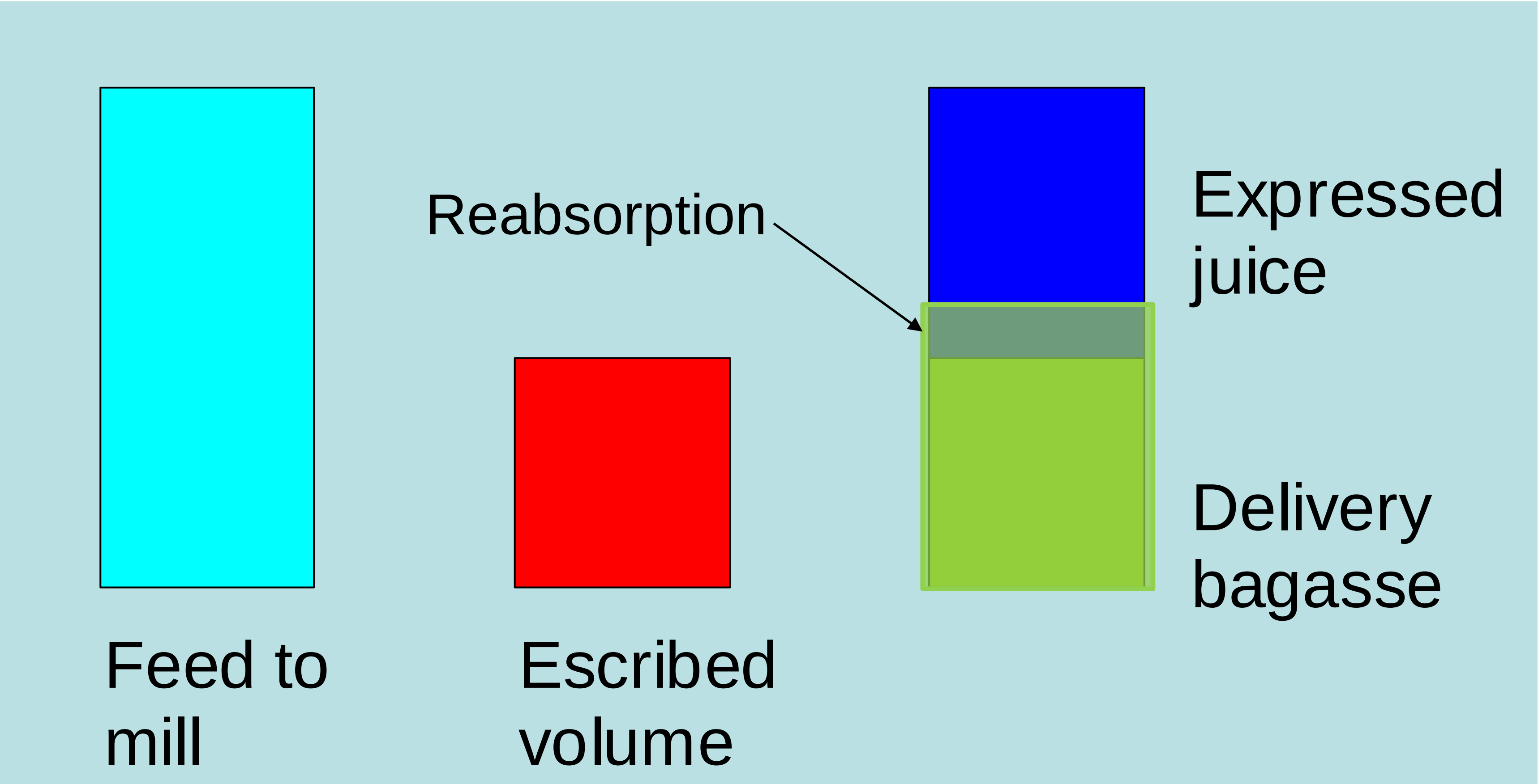


How to change bagasse softness?

- Change added water temperature
- Higher temperature softens the fibres

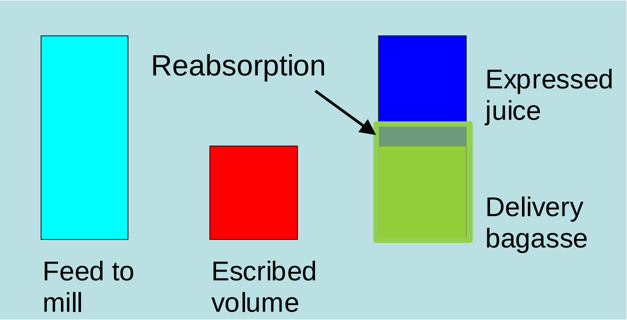


The real extraction process



Increasing extraction approach 2

- Based on volumetric theory
- Reduce reabsorption factor (*k*)
- Volume of bagasse (based on fibre rate and delivery bagasse constituents) larger than escribed volume



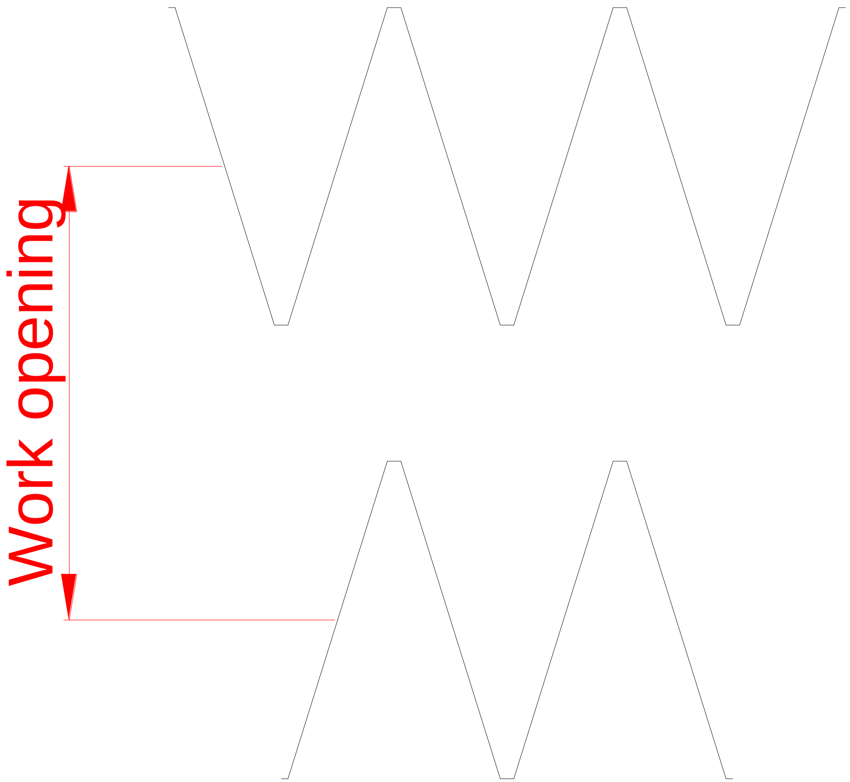
$$k = \frac{V_B}{V_E}$$

Understanding reabsorption

- Strongly dependent on definition of escribed volume
  - Definition of work opening W
  - Definition of surface speed S

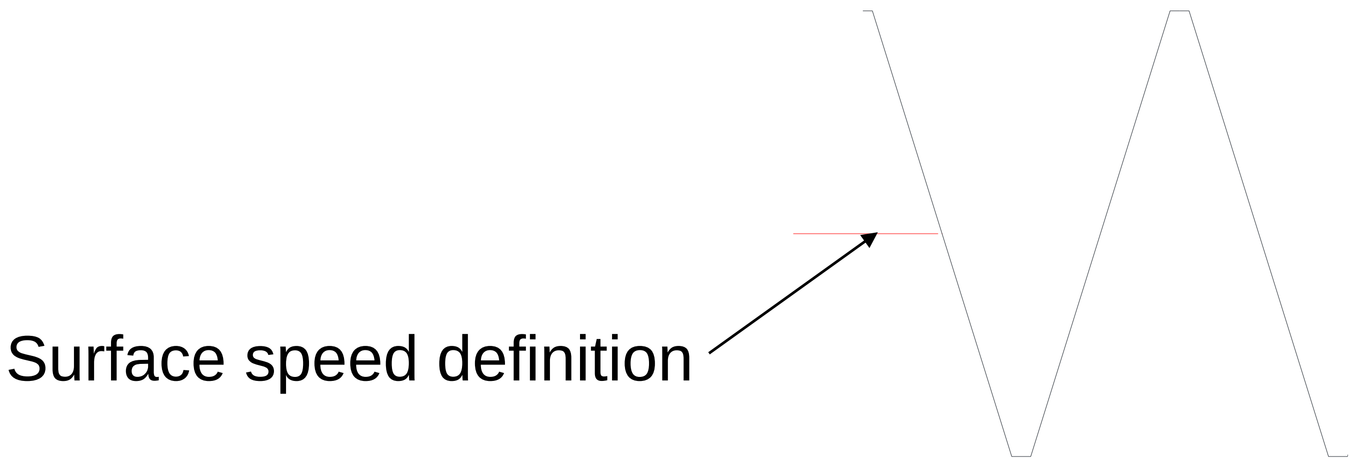
Definition of work opening

- Defined half way into grooves
- Assumes:
  - Tip area inside work opening space where bagasse cannot fill is same as groove area outside work opening space where bagasse can fill
  - Groove is filled with bagasse



Definition of surface speed

- Also defined half way into grooves
- Defined for top roll only



For reabsorption to occur…

- Need to have more bagasse passing through nip than indicated by escribed volume definition
  - Consider fibre and juice

Possible mechanisms of reabsorption

- Juice flowing forward through or around grooves
- Bagasse slipping forward between rolls
  - Insufficient roll roughness to grip bagasse
- Bagasse extruding forward due to internal shear

Juice flow over rolls

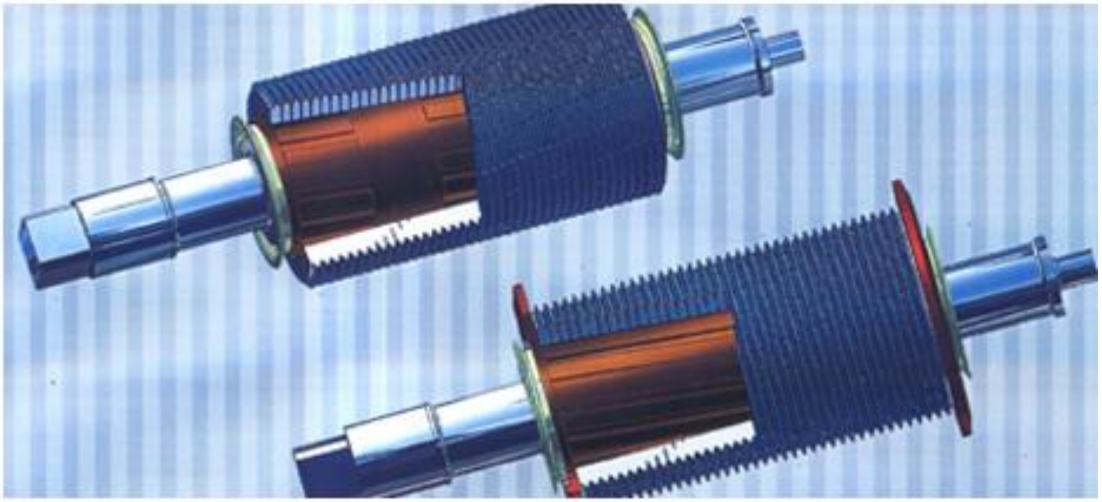
- Particular problem for four-roll mills

Juice suction system

- Option to extract juice from behind the top roll before it flows over the top
- Four-roll mill experiment found juice suction reduced reabsorption factor by 5%

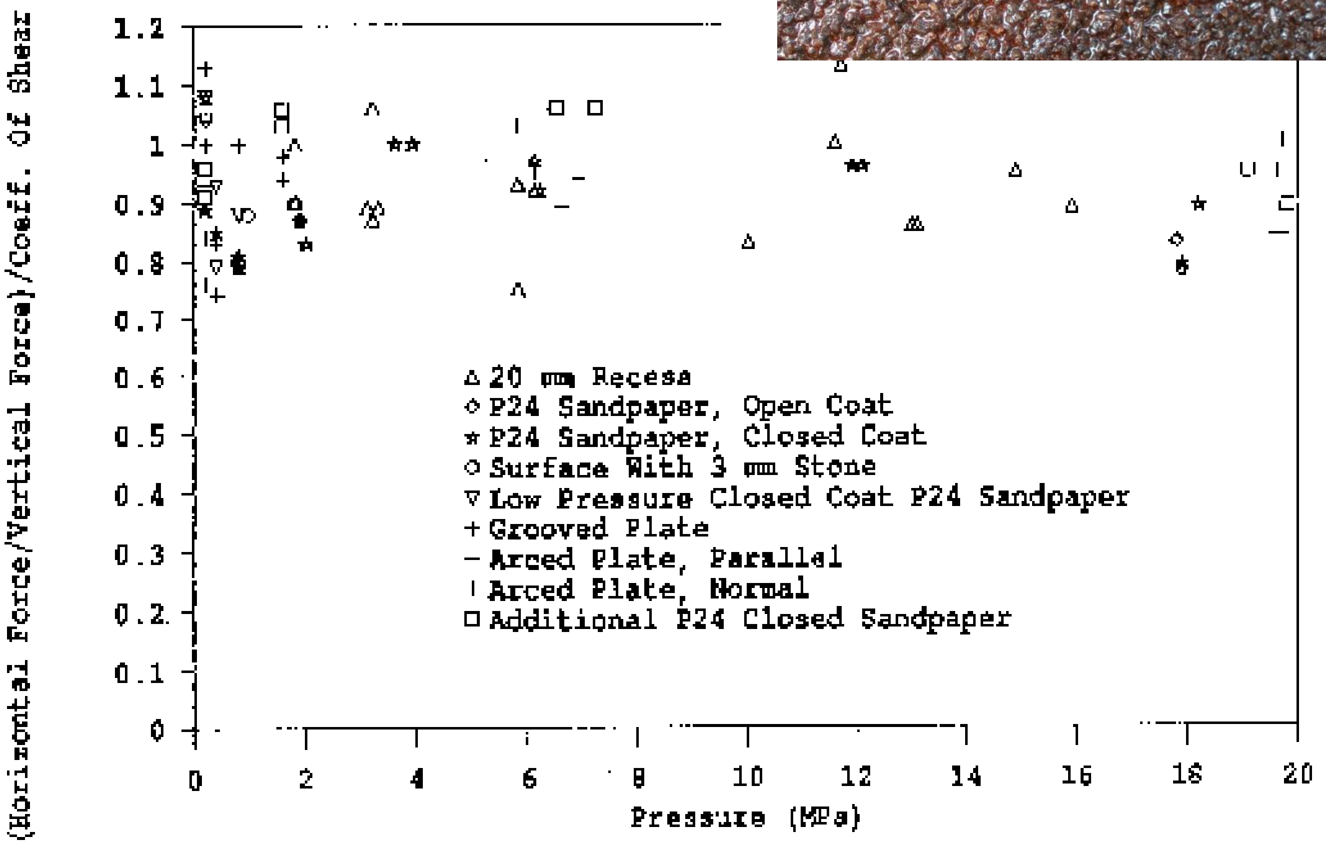
Lotus rolls

- Significant increase in popularity in last few years
- Ability to draw in juice and prevent it from flowing over top roll
- Good option for four-roll mills



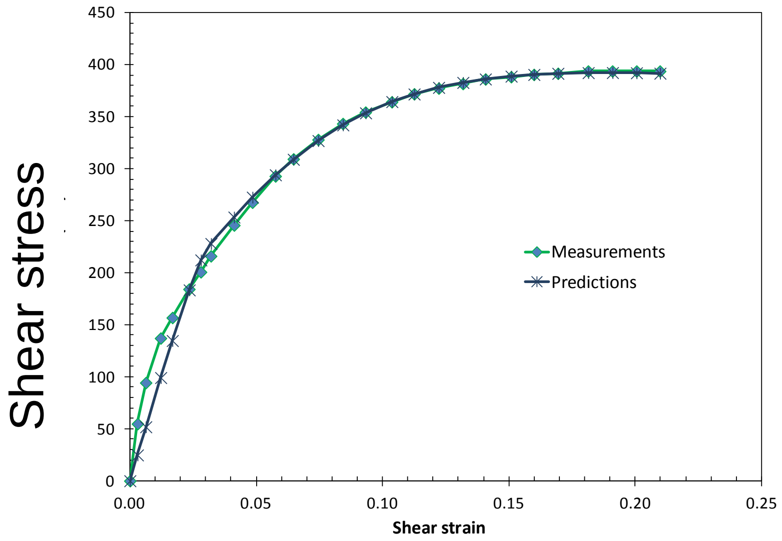
Bagasse slipping forward

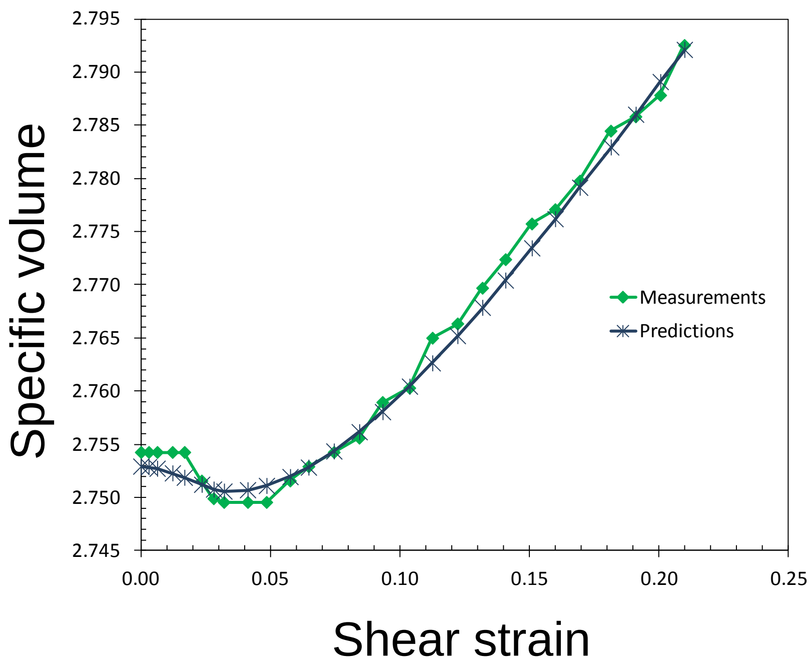
- Tests have shown that a rough sandpaper (P24) is sufficient for bagasse to grip



Bagasse shearing

- Stress/strain behaviour of bagasse is complex
- Finite element analysis modelling has provided some insights of stress states of bagasse in mills





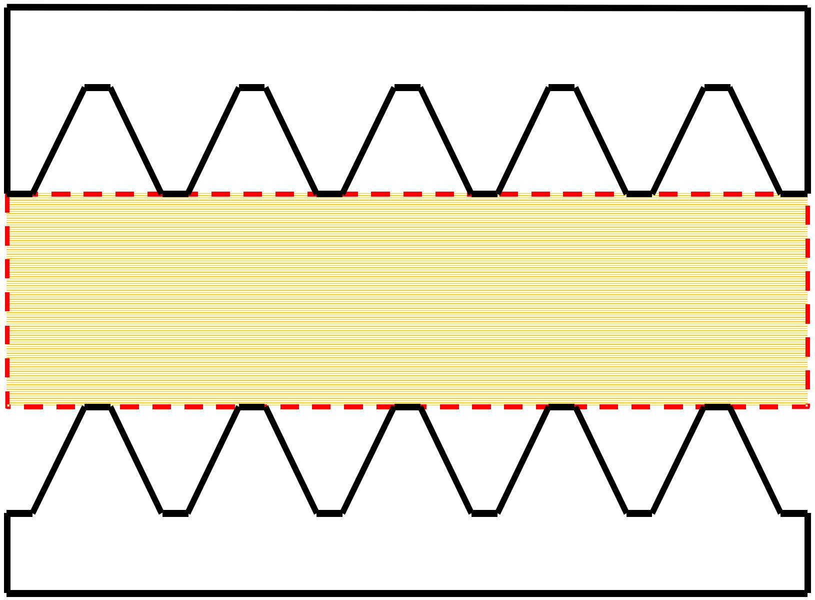
Other methods of controlling reabsorption

- There are few conclusive methods for reducing reabsorption
- Some options that may help
  - Groove profile
  - Roll roughness
  - Mill ratio
  - Trash plate design and setting
  - Mill control

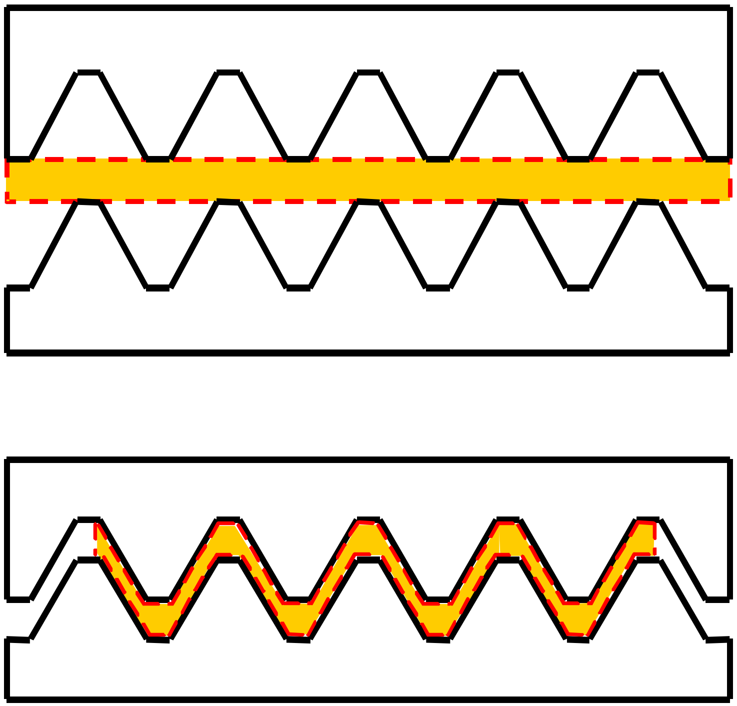
Groove profile

- Conducted compression tests with a range of groove profiles
  - Pitch
  - Angle
- Better extraction with
  - Higher pressure
  - Larger sample (work opening)
  - Wider angle

Why may wider grooves be better?



Initial state



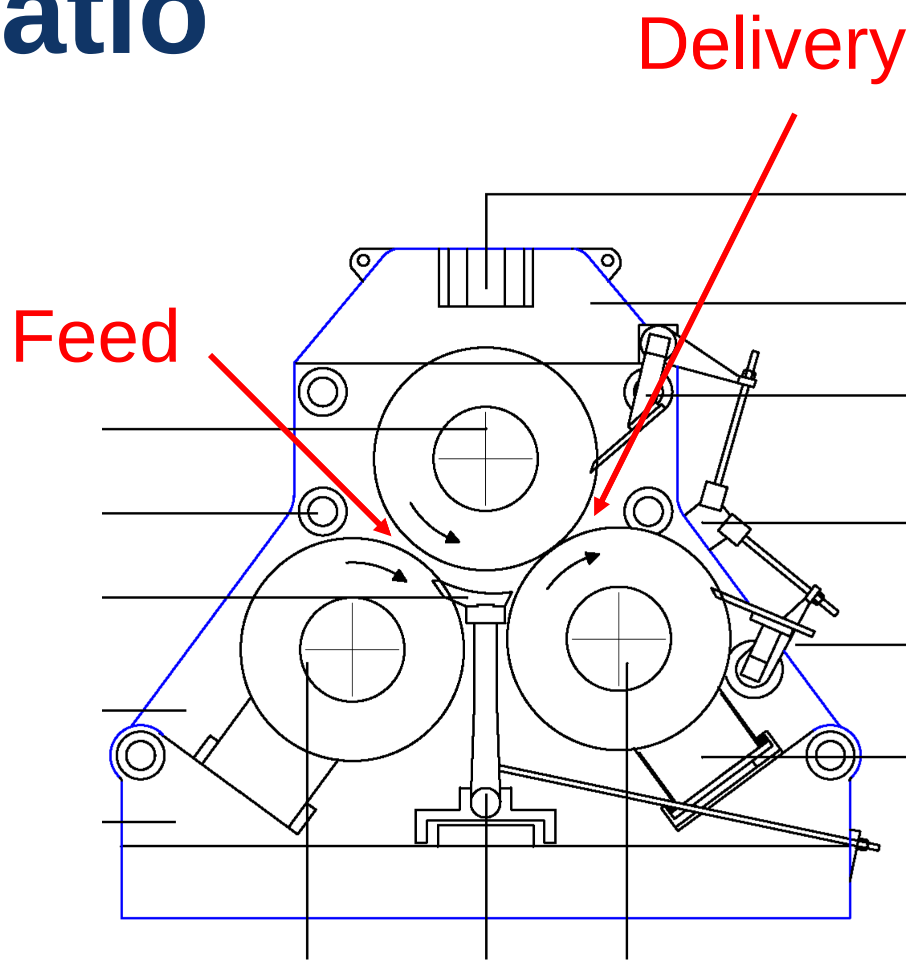
Possible final states

Roll roughness

- One Australian sugar factory used to use reabsorption factor measurements to determine when to arc rolls

Mill ratio

- Ratio of escribed volumes of feed to delivery
- Low mill ratio expresses more juice in feed nip so cannot be reabsorbed in delivery nip
- Low mill ratio reduces load that can be applied at delivery nip and so reduces delivery escribed volume

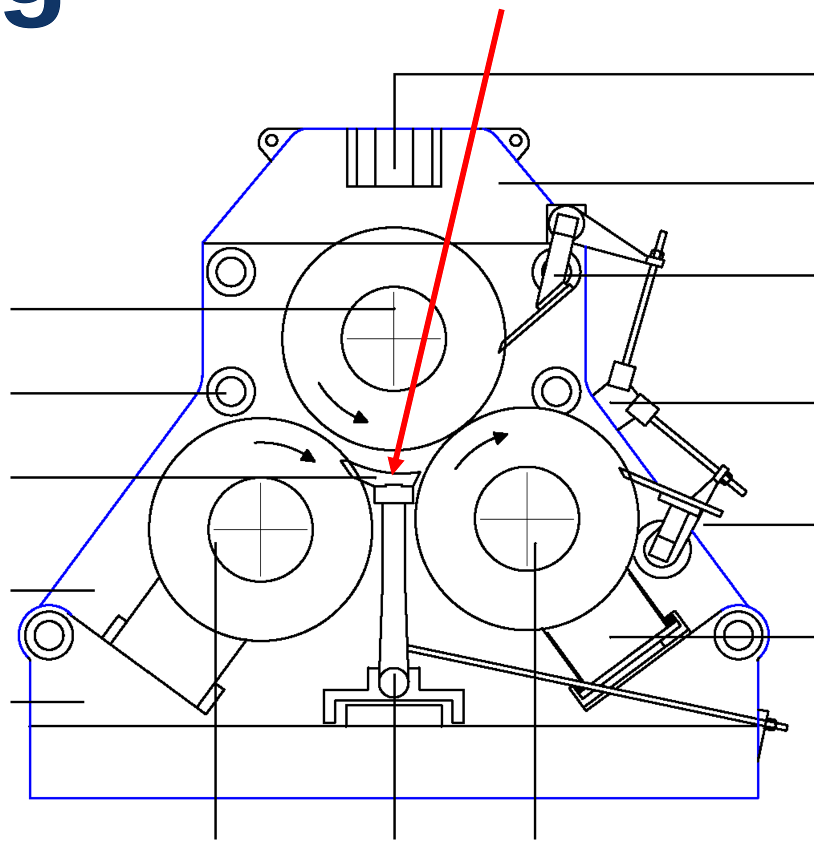


Mill ratio

- Some Australian mills use reabsorption factor as a guide for adjusting settings
- High reabsorption factor
  - Reduce feed nip setting
- Low reabsorption factor
  - Reduce delivery nip setting

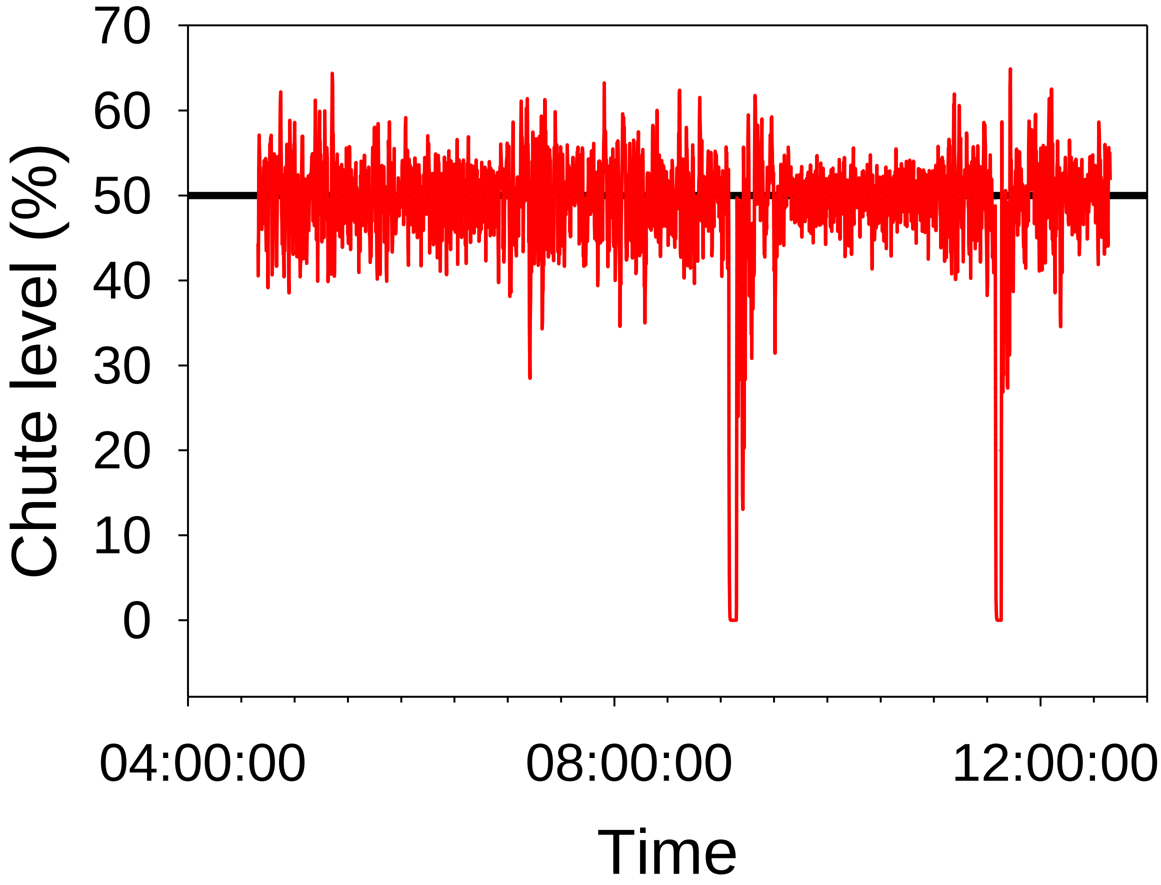
Trash plate design and setting

- Expect that trash plate design and setting will affect reabsorption factor
- No real evidence to suggest how
- Wide range of designs and settings that seem to function



Mill control

- Good mill control can lead to lower reabsorption factors



Power consumption

Reducing power consumption

- From roll load theory

$$R \propto LD(C_F - 0.1)$$

- R Roll load
- L Roll length
- D Roll diameter
- C_F Filling ratio (compaction)

- Power consumed between pairs of rolls
- Power consumed when pushing bagasse across plates

Reducing power consumption

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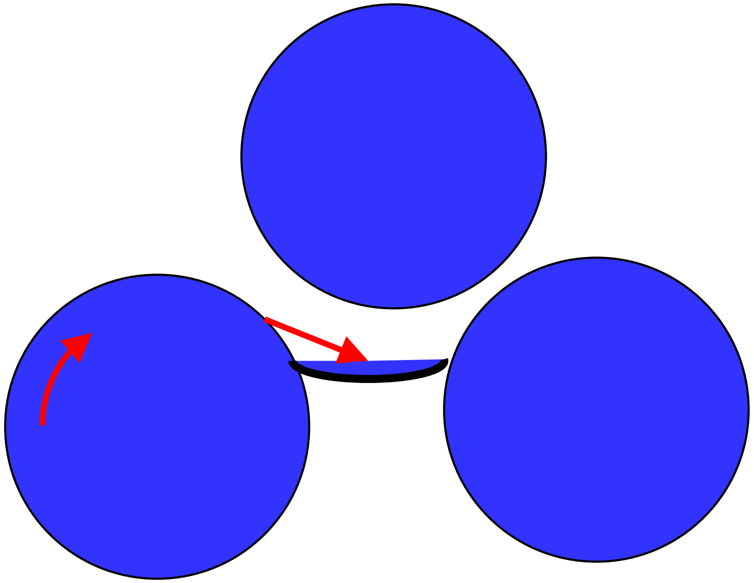
- Power consumed between pairs of rolls
- Power consumed when pushing bagasse across plates

Power consumption in a four-roll mill

- Not much can be done to reduce power consumption in a four-roll mill without affecting performance
- Two-roll mill designs have the advantage of no trash plate
  - Generally lower capacity

Trash plate effect

- From studies of mills with independent drives, torque on feed roll is of similar magnitude to torque on delivery roll, even though compaction is a lot lower
- Hypothesis that feed roll pushes bagasse across trash plate



Power consumption innovations

- More efficient drives
  - Low efficiency steam turbines replaced by higher efficiency electric motors
    - Hydraulic transmissions
    - Variable speed drives and mechanical transmissions
- Independent drives
  - Pinionless mills

Power consumption innovations

- More efficient mill couplings
- Rope couplings reported to reduce power consumption by 8% compared to tailbar couplings

Image and results from Sundaram et al (2016)