Microchips

Comparing Wood Microchips to Conventional Wood Chips (typical analysis) & The Application of Microchips to Some Common Types of Biomass Processes

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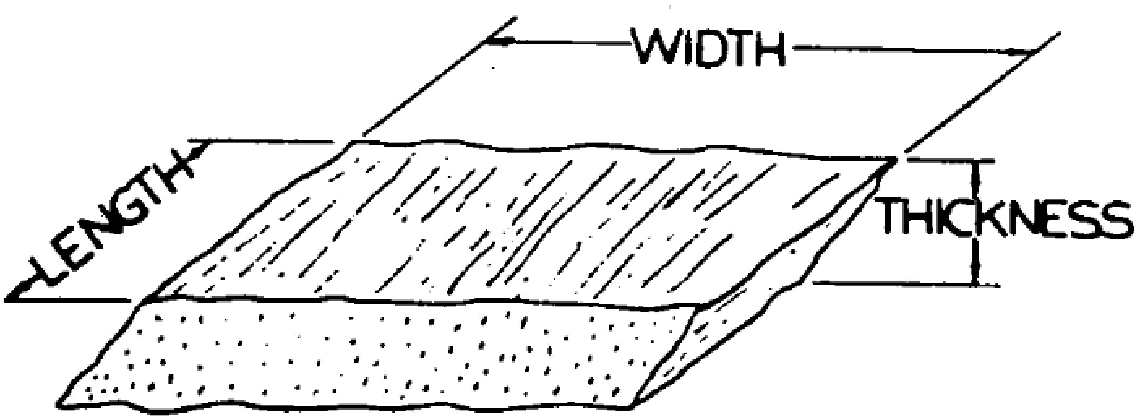
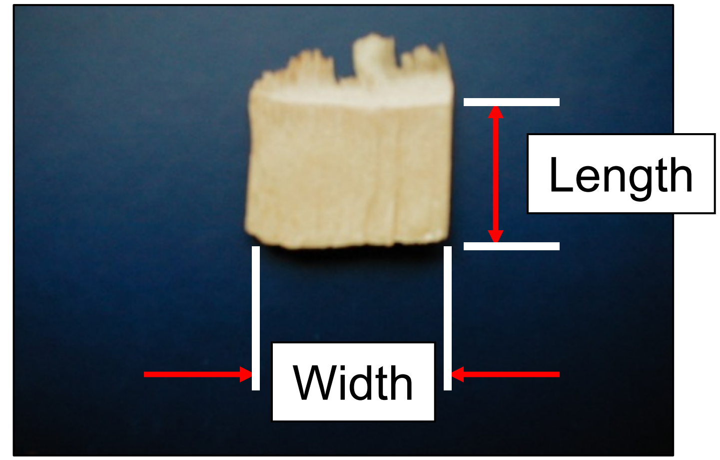
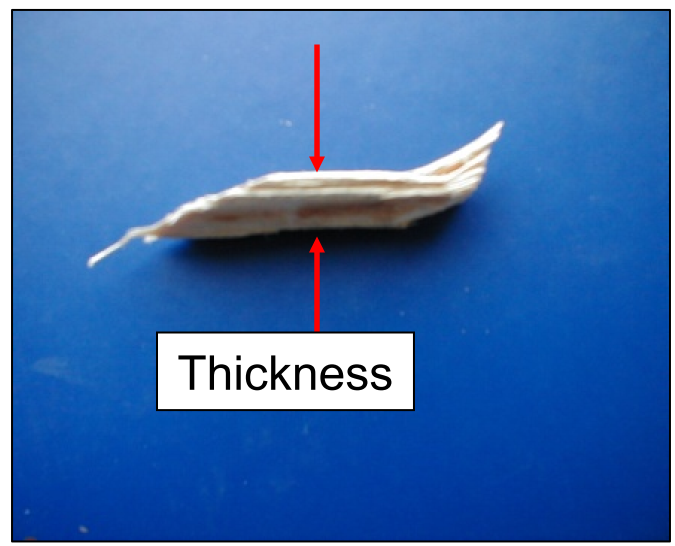
Chip Dimensions - Definition



Orientation of Chip Dimensions





Note: Most chip data reported here uses round hole classifiers that directly test for a composite of primarily only the smallest two dimensions

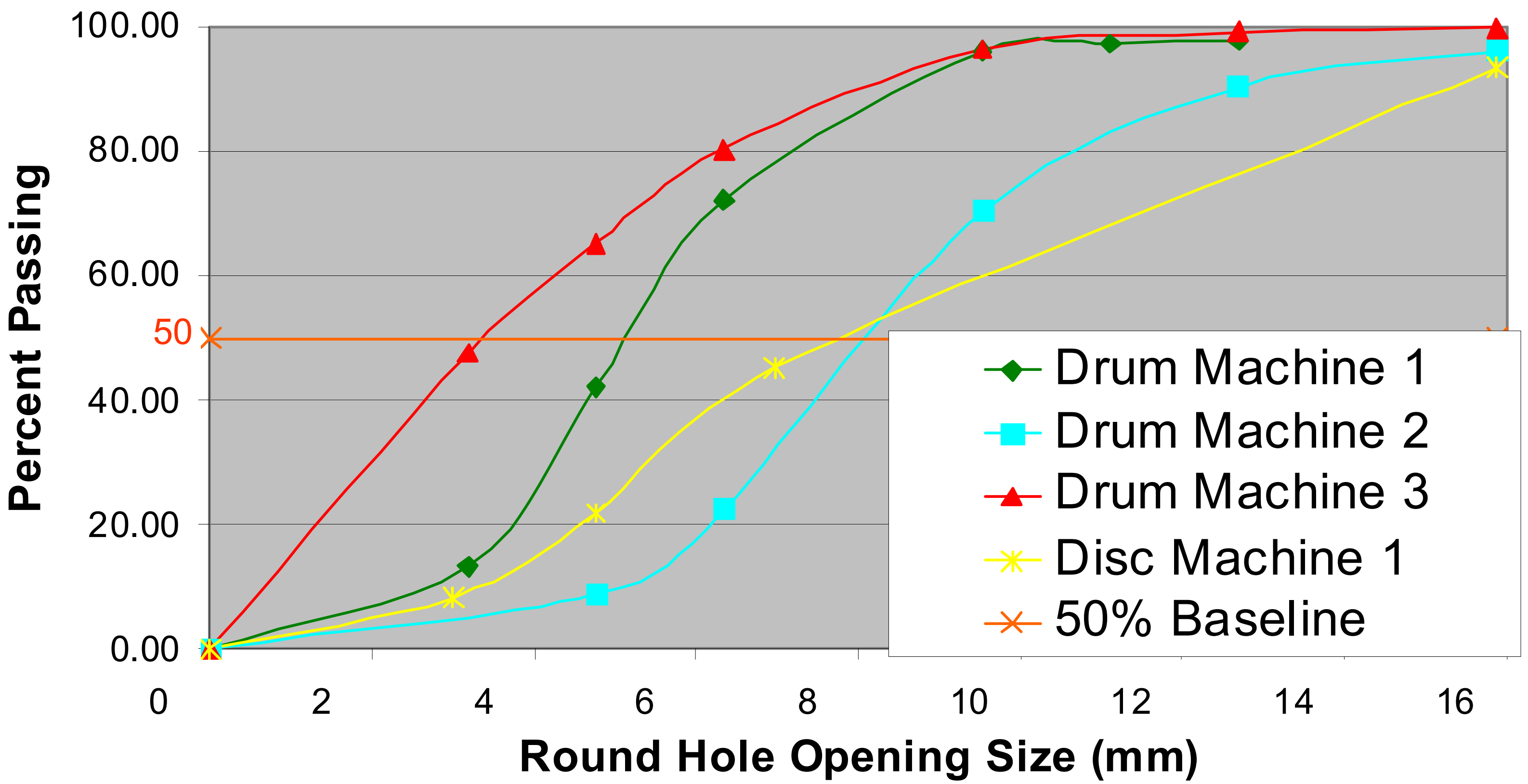
Wood "Microchips" as Presented Today

- Miniature conventional wood chip
- Mean size: 6 -10 mm (1/4" - 3/8") nominal length
- Homogeneous size with few associated fines (in some cases)

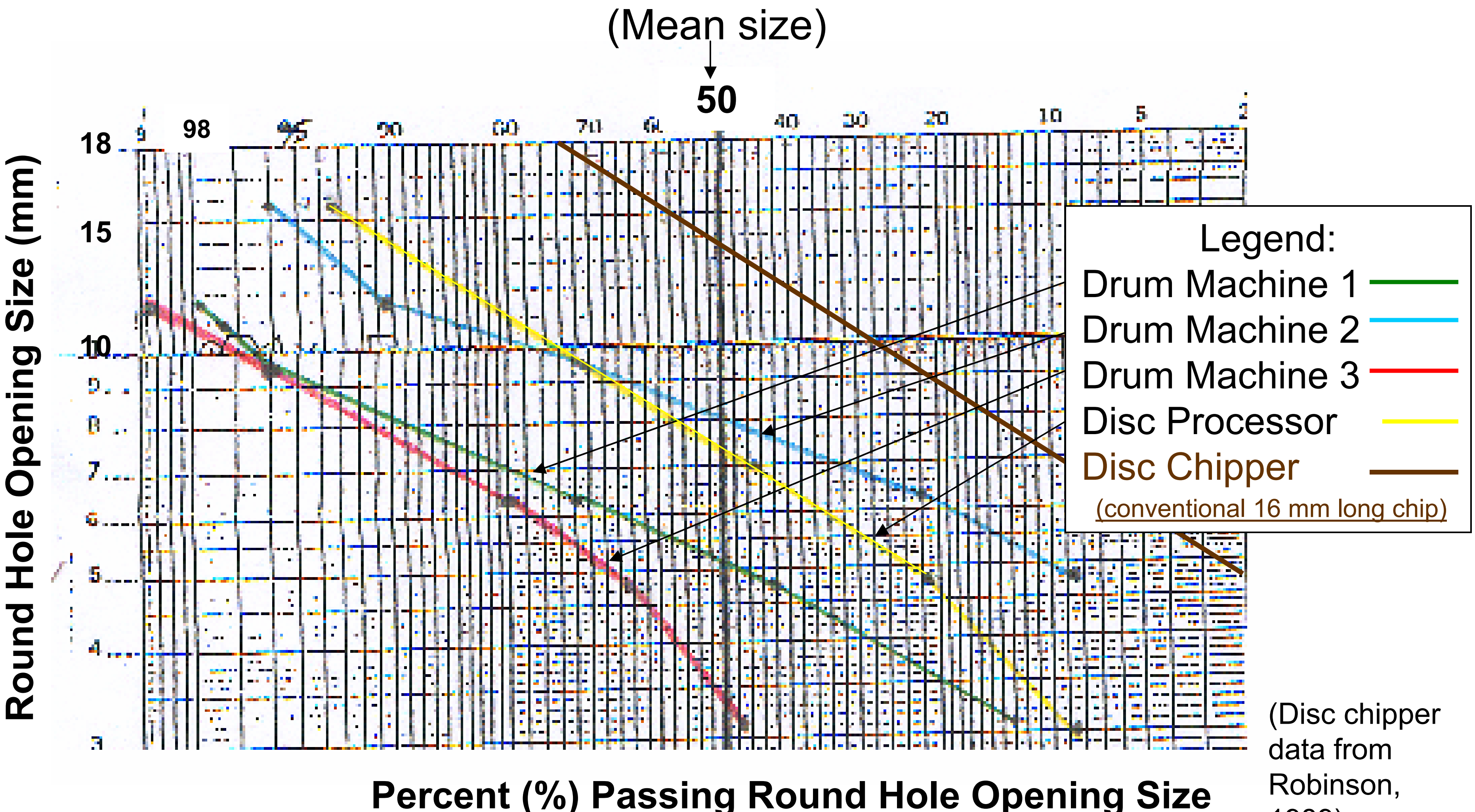
Typical 20 mm long wood chips

Wood Microchips

Microchip Size Distribution for Four Microchippers

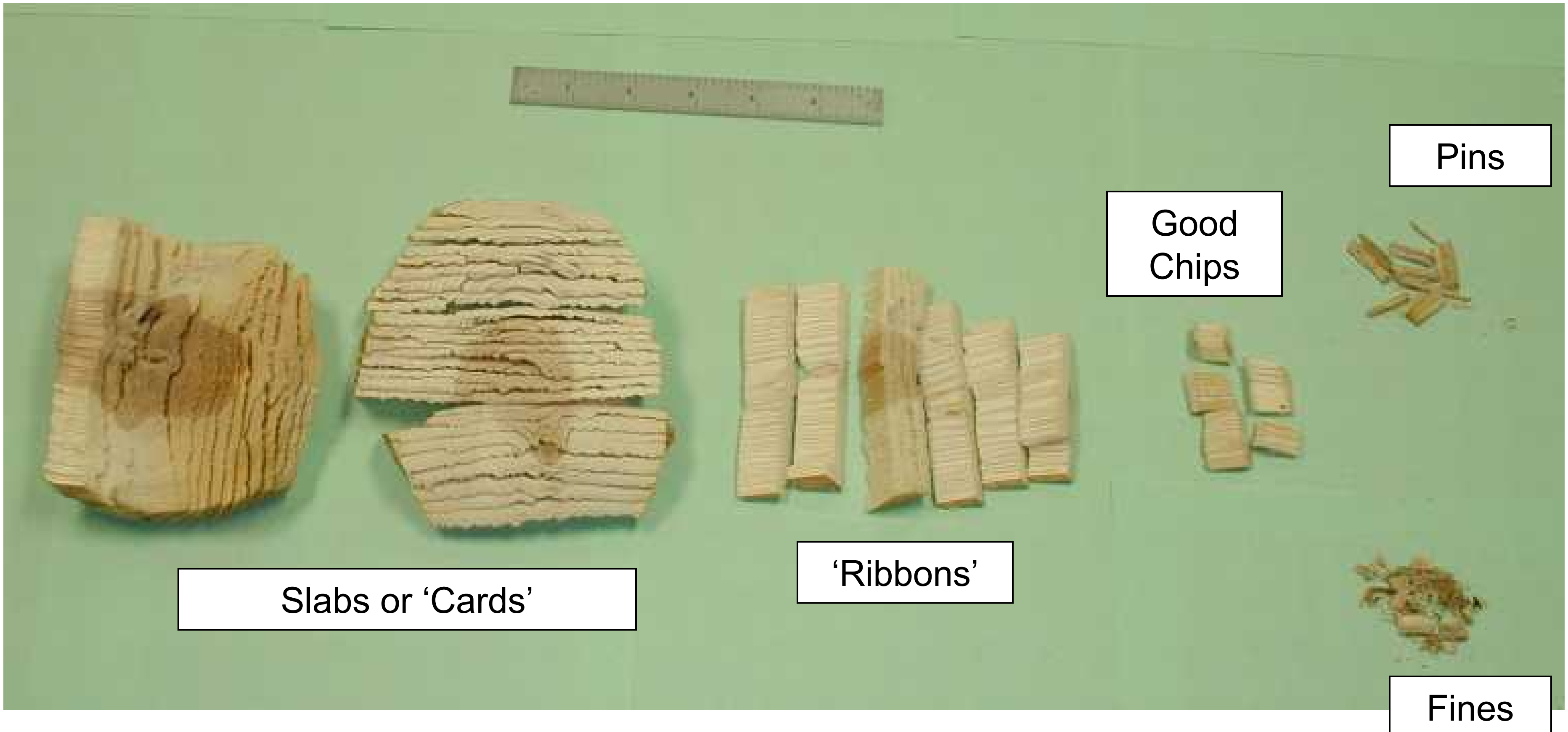


Typical Microchip Size Distributions



(Disc chipper data from Robinson, 1989)

Chip Formation



Normal Chip Formation Progression in a Disc Chipper

Note that except for the fines fraction, all chips are cut to uniform length

Microchip – Typical Specified Characteristics

- Small size (compared to conventional chips)
- Large specific surface area
- Acceptable Packing Density
- Homogeneous size
- Clean (very little bark, sand or grit)
- Often with little dust/fines

Chip dimensions Compared
20 mm conventional Chips and 10 mm Microchips

Conventional chip volume:

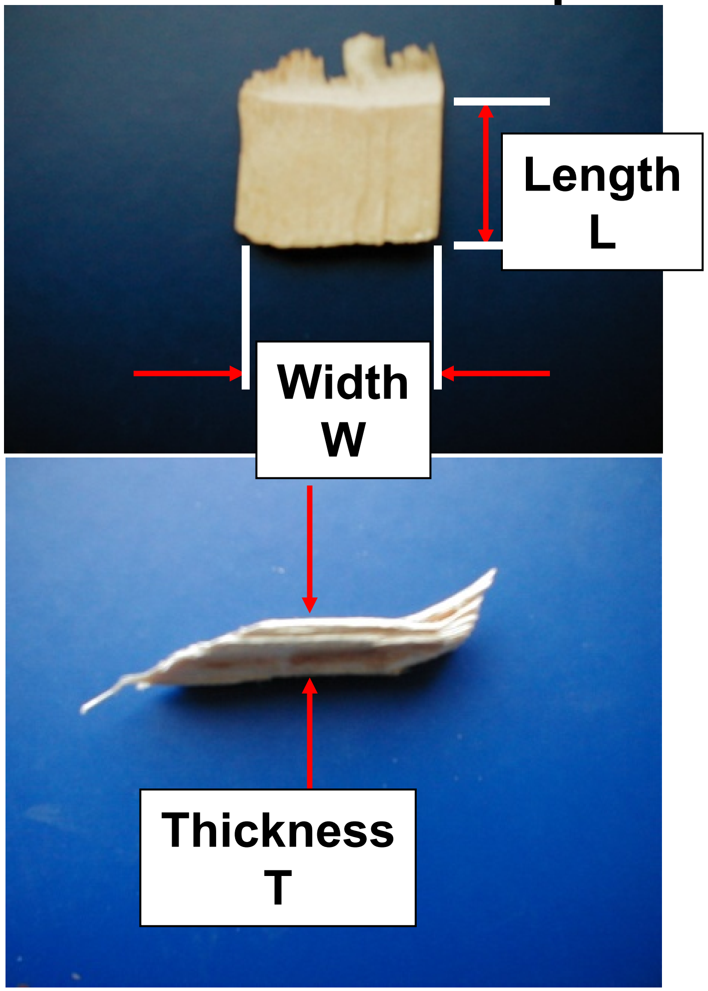
$V_{conv} = L \times W \times T$

Microchip main dimensions are halved, so microchip volume:

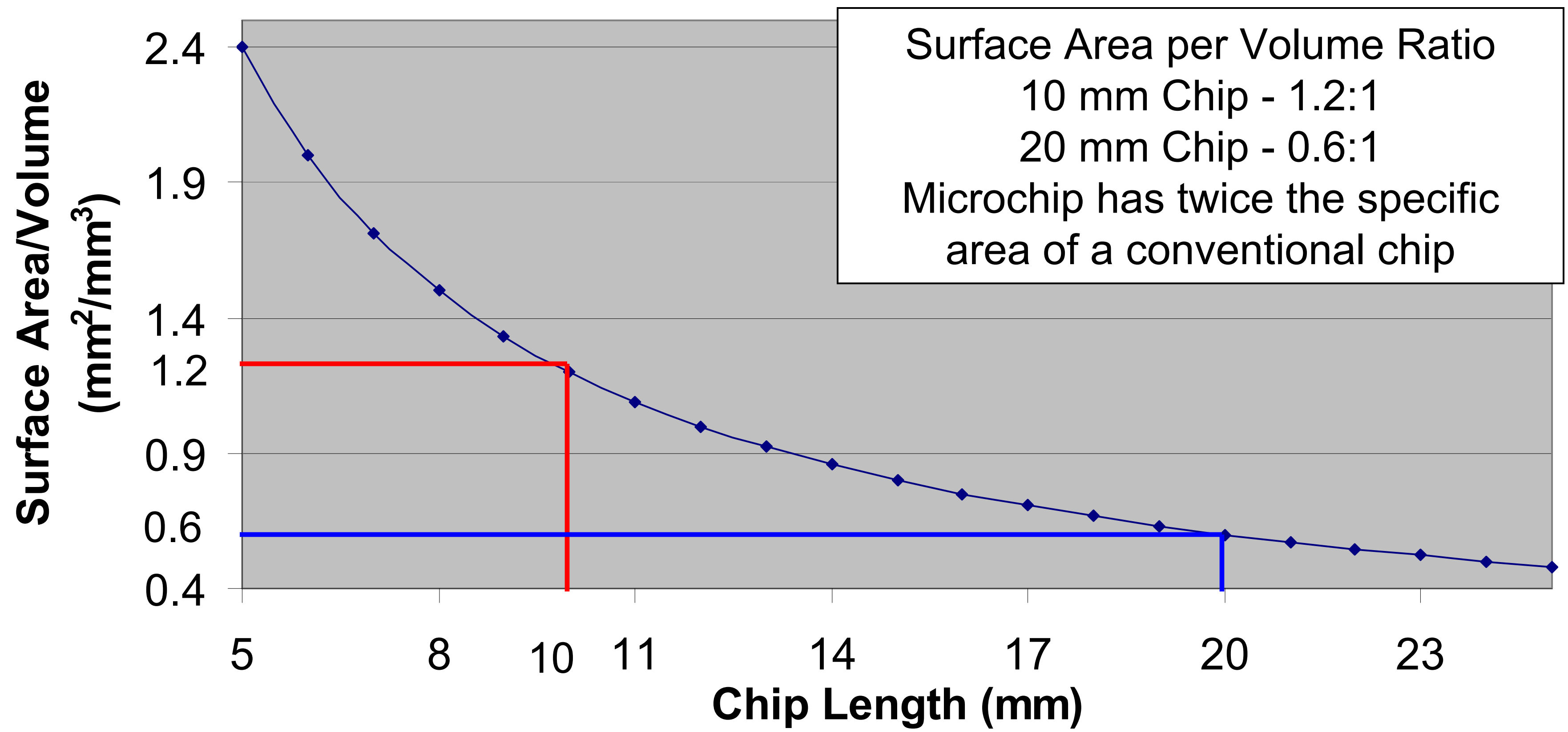
$V_{micro} = 0.5L \times 0.5W \times 0.5T$

$= .125 \times L \times W \times T = .125\ V_{conv}$

10 mm Microchip weighs 10%-15% the weight of a conventional 20 mm conventional chip



Ratio of surface area per volume depending on chip length



Where Length = Width = 4 X Thickness

Potential System Advantages of Small Chip Size & Large Specific Surface Area to Bioprocessing Plants

Significance of chip properties is often erroneously overlooked in plant design (Hakkila, 1989)

- Economics:
  - The minimized wood cost approach vs.
  - The minimized total cost approach (Bjurulf, 2006)

Potential System Advantages of Small Chip Size & Large Specific Surface Area to Bioprocessing Plants

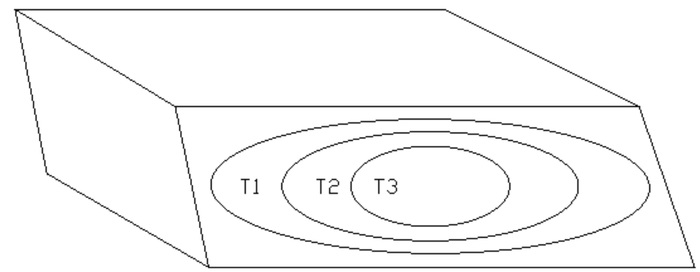
Possible significant savings in subsequent processing:

- Lower overall *total* system energy or chemical consumption
- Faster processing times, lower inventories
- Smaller process equipment sizes
- Fewer processing steps for higher system operating efficiency (Bjurulf, 1990)

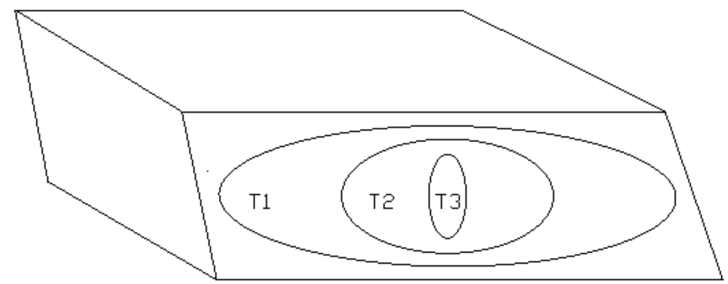
Process characteristics of wood microchips

Chemical Bioprocesses

- Small dimensions → faster penetration
- Chemical processes such as pulping depend on smallest dimension (Hakilla, 1989)
- Raising pH increases penetration rates (Higher alkalinity →more chip swell) (Fahey, 1990)
- Homogeneous chips cook more uniformly (Hakkila, 1989)
- If an objective is cellulose by-product (such as paper), beware that pulp strength will not be optimal



Alkaline Bath



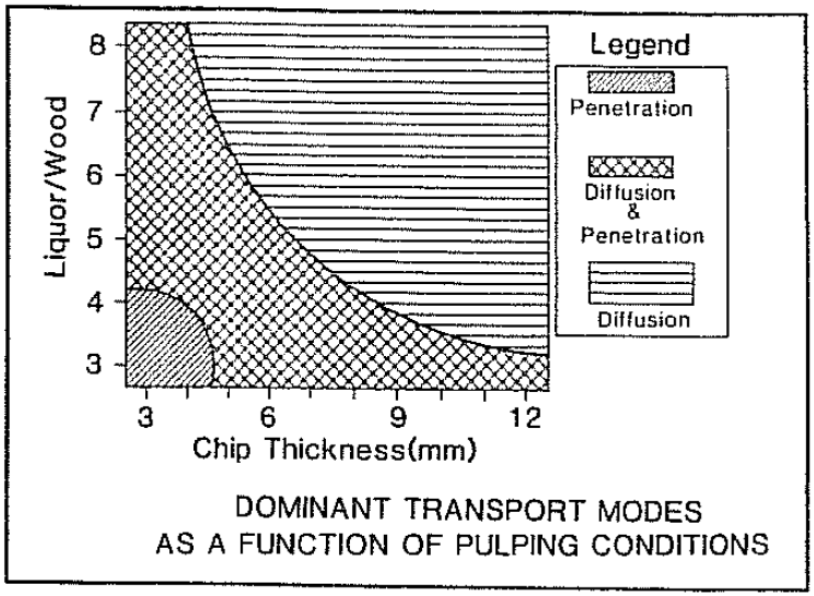
Acid Bath

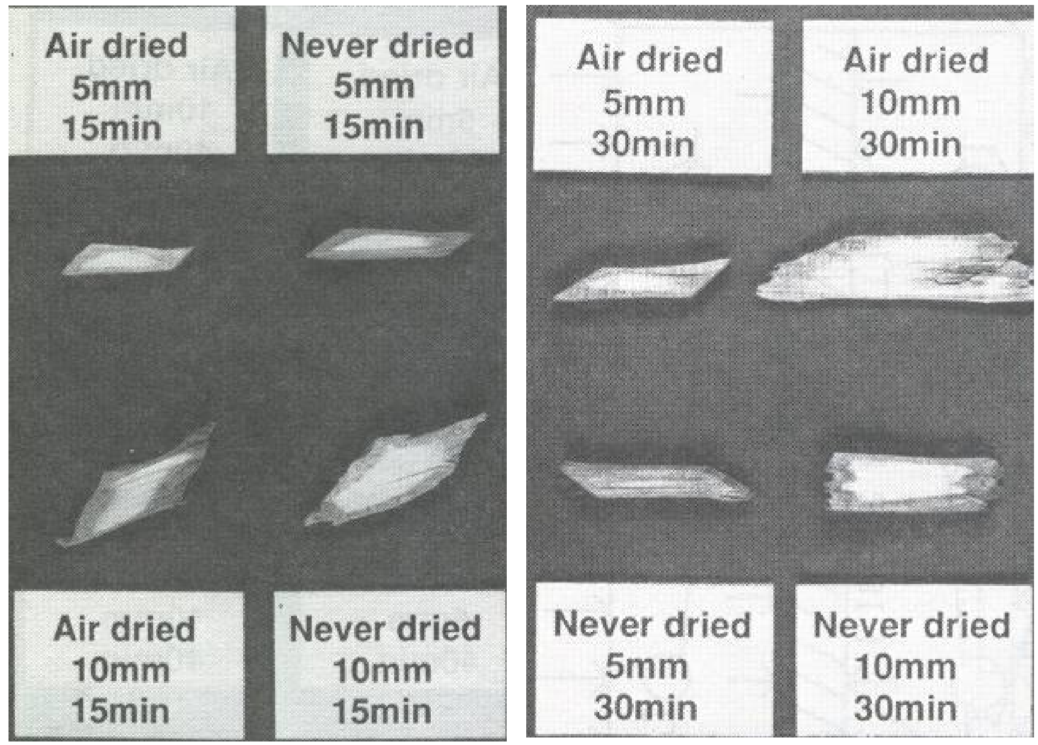
Process characteristics of wood chips

Chemical Diffusion/Penetration in

Or water Expiration out

- **A thinner, smaller chip works better**





Penetration of an alkaline liquor as a function of chip thickness

(Images from Gustafson, 1988)

Process characteristics of microchips

Thermal (burning, torrefaction, etc)

- "Average particle size may be of significance" (Hakkila, 1990)
  - Homogeneous chips are optimal
- Typical high quality chip sizes to feed woodchip boilers are 10x10x5 mm - 15x15x8 mm (Abdallah et al, 2011)
  - Microchip to small conventional chip
- Gasifiers
  - Require 10x5x5 mm - 80x40x40 mm biomass particle
  - As small as 0.1 mm diameter for fluidized gasifier
- *Beware of possibility of air/dust mixture explosion*

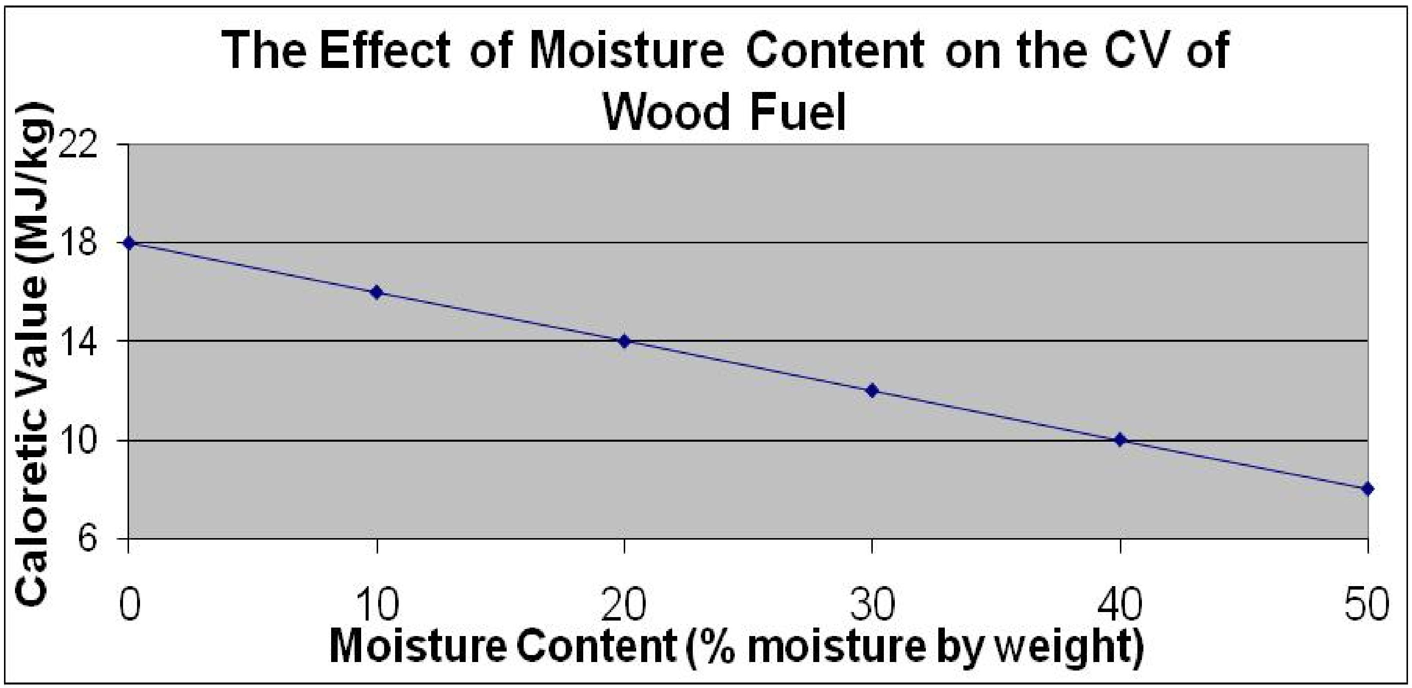
Organic:

- Higher rate of diffusion / expiration

Process characteristics of microchips

"The effect of moisture on wood fuel can be very dramatic" (Swithenbank et al, 2011)

- **A microchip has a greater expiration rate**
  - Every 10% moisture increase reduces CV (caloretic value of fuel) by 2 MJ/kg (Swithenbank et al, 2011)

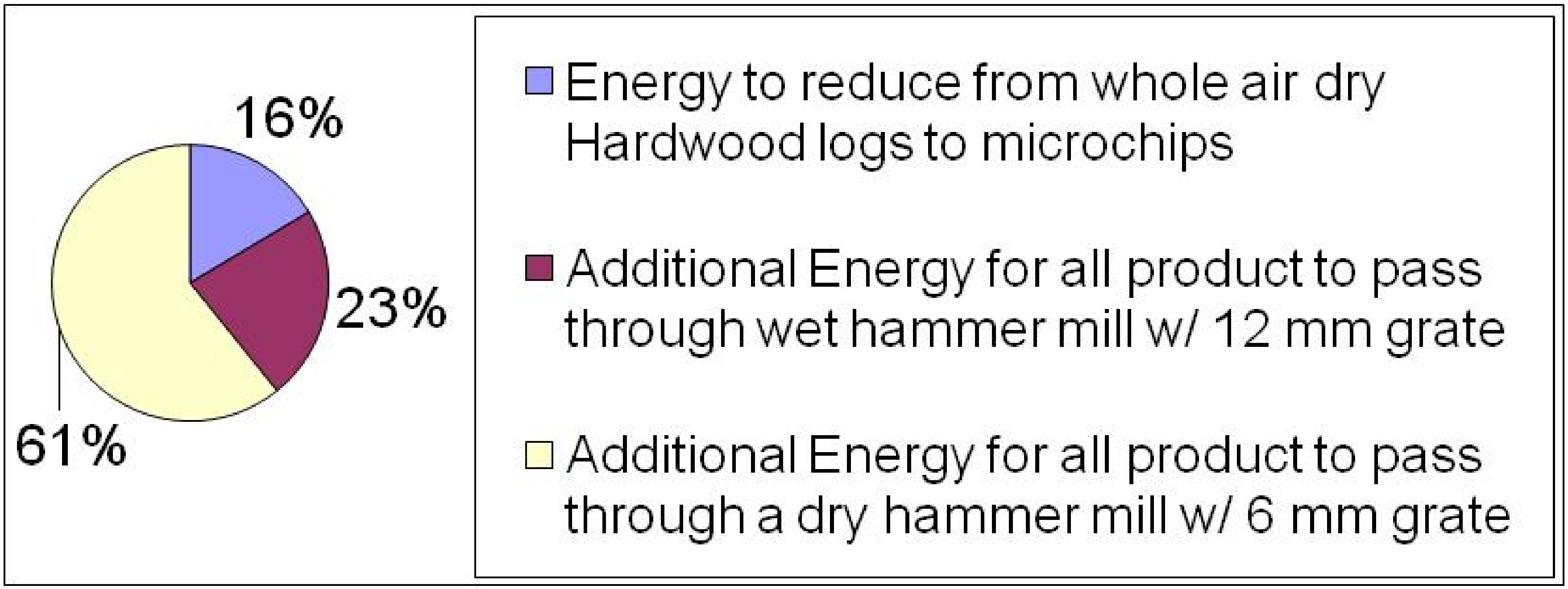


Process characteristics of microchips

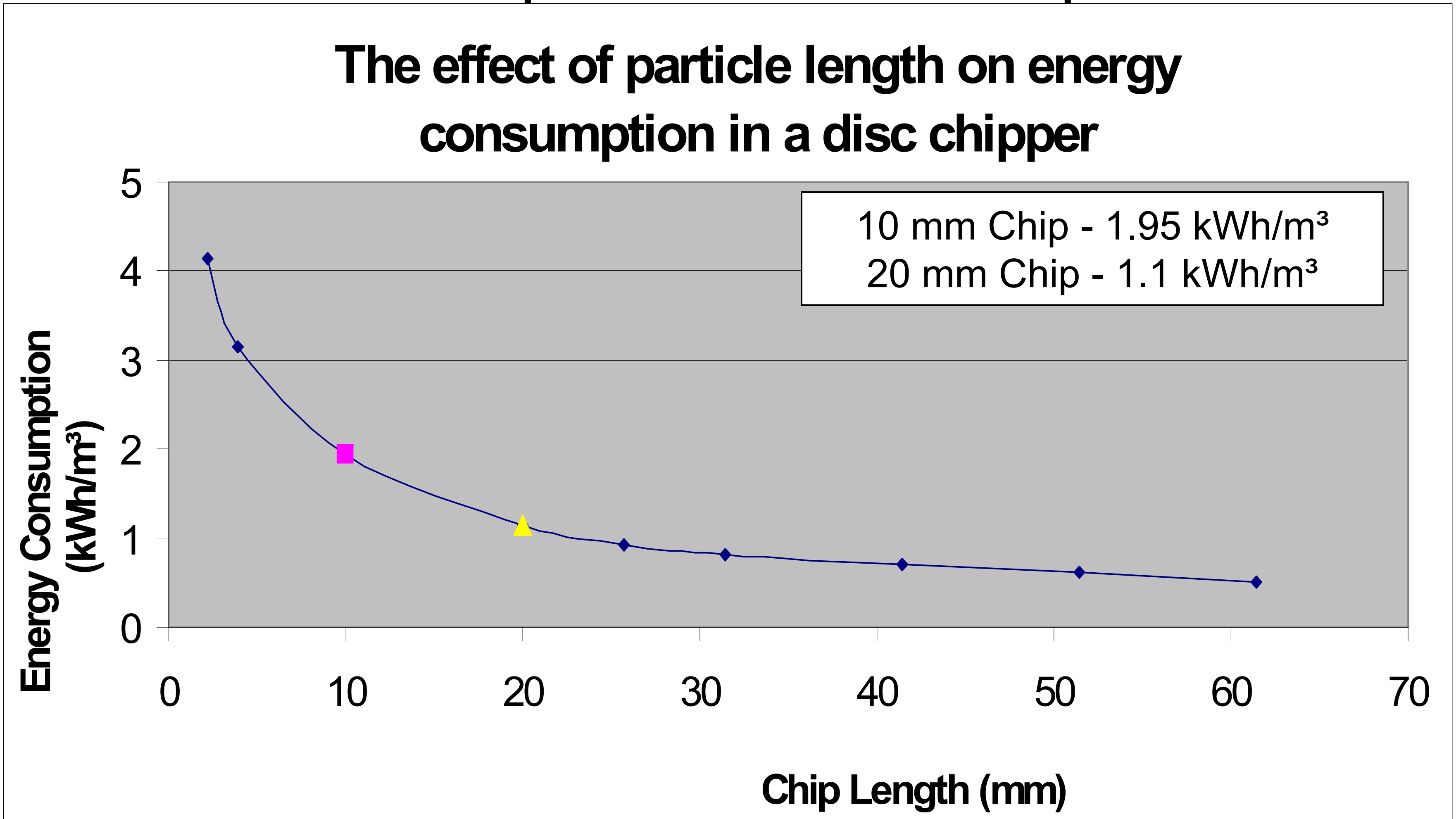
Mechanical Biomass Processes

- Smaller wood particles reduce more efficiently

Results from a pellet manufacturing mill with disc-type microchip processor



Microchip Power Consumption

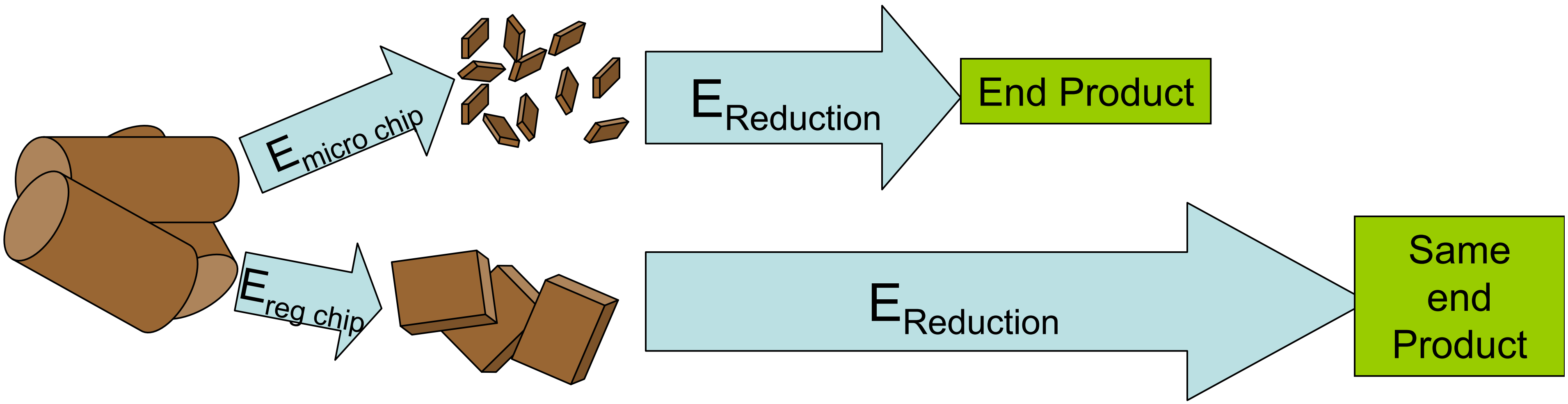


(Murto & Kivimaa, 1951)

System Power Consumption

Chipping energy is usually only a small portion of the total energy consumed in the entire production process

Using a little more energy in the chipping phase will significantly lower overall system energy consumption



Total energy expended depends on furnish and process used, as well as end product required.

BioPro expo&marketplace 2011

TAPPI people resources solutions

Possible Microchip Disadvantages

NOT optimal for all processes

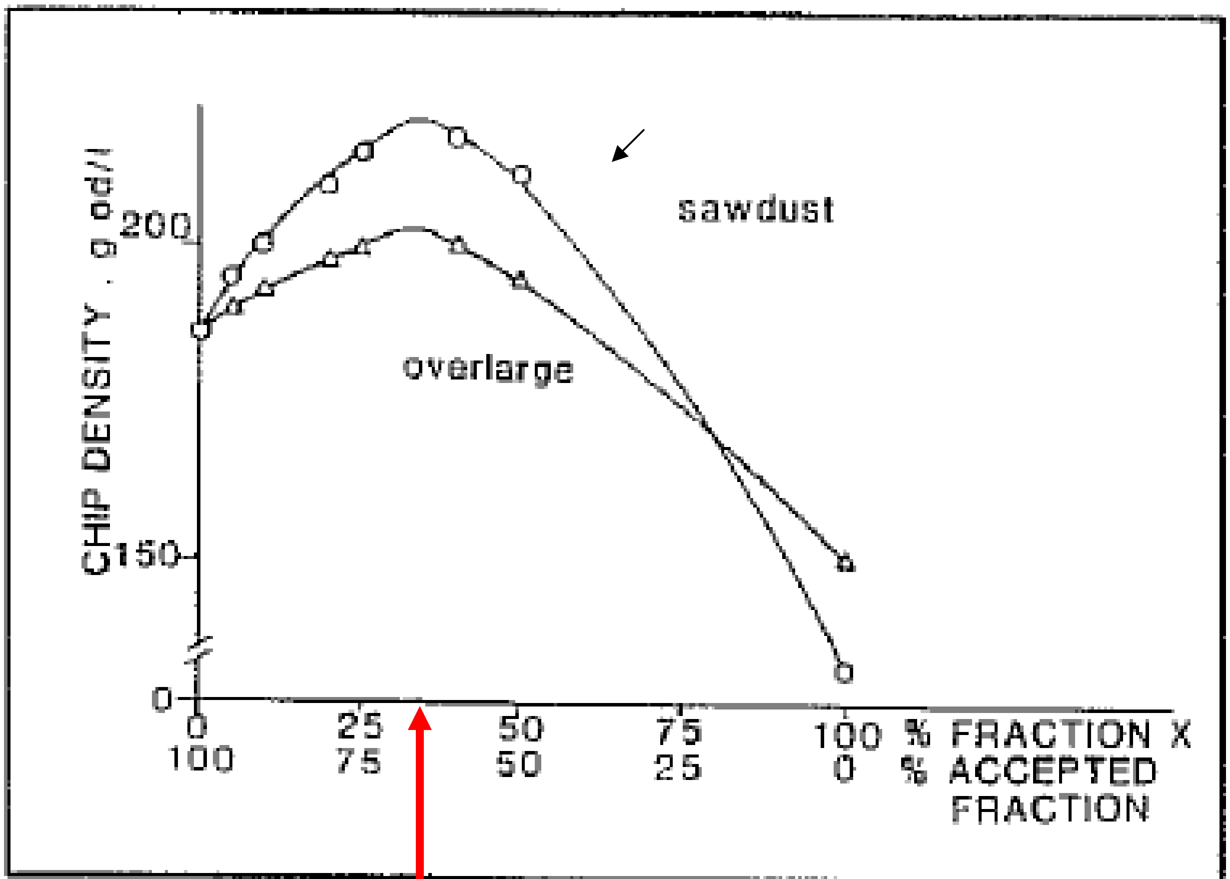
- More energy required per unit volume of wood to produce a microchip (compared to conventional chip)
- Chipper primary cutting knives wear faster (per unit volume or weight of wood) because *more cutting is done*
- Larger chipping equipment is required because additional cutting requires more machine capacity (for higher production rates)
- Microchips may not be a product that is compatible with *existing* chip handling or system process machinery

Potential problems

Characteristic of Microchips

- Lighter (lower bulk density)
- Contains More fines and dust
    - Increased losses (wind-blown)
    - Risk of fire or explosion
- When contaminated, can cause clogs
    - Reduced efficiency
    - flow problems, pressure drops
- Greater process difficulty in segregating fines & dust
- Decays more quickly in storage

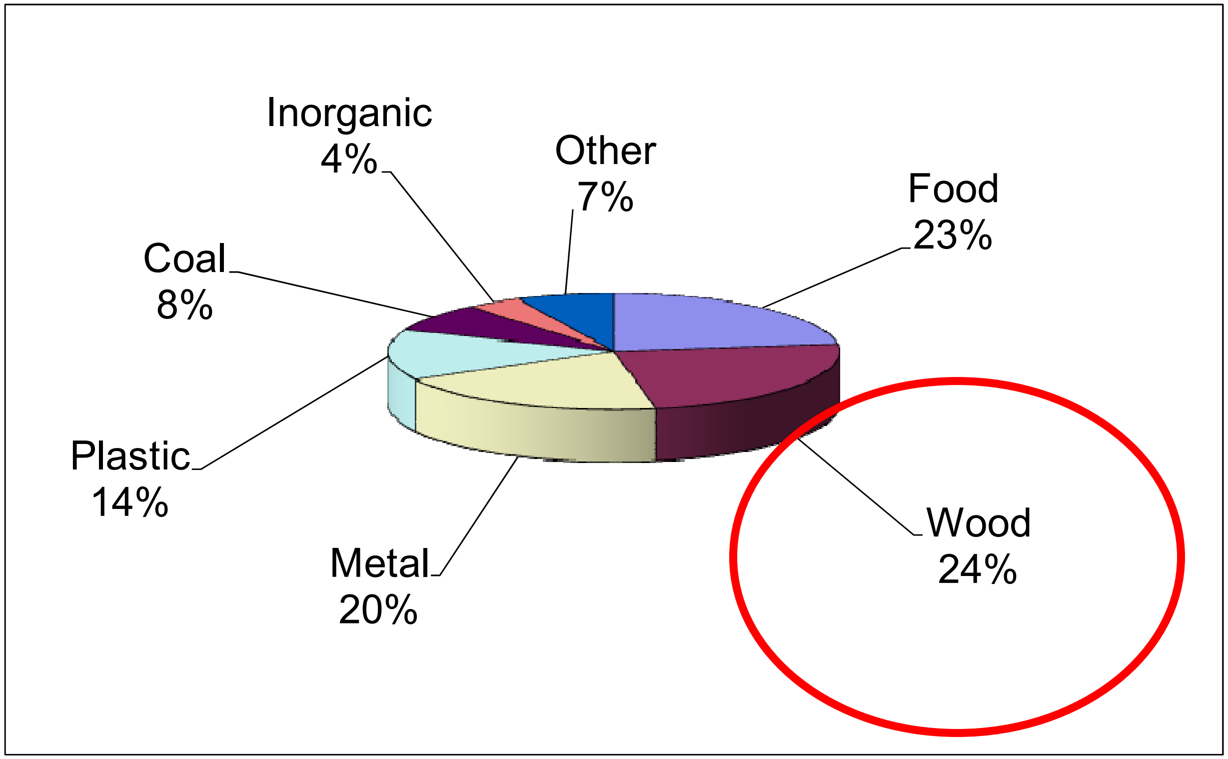
Dry Bulk Density of Chips



Bulk Density of woodchips falls off as small chip fraction increases above 35% of the total chips

Possible Microchip Disadvantages

Nearly 300 Types of Dust-involved Incidents
(combustible dust fires and explosions) in US industry
1980-2005



(Collyer, 2001)

Possible Microchip Disadvantages

NOT optimal for all processes

Dust Explosion killing 3 at West Pharmaceuticals, Kinston, NC, January 2003

(Collyer, 2001)

Wood Reducing Machines

Non-chippers

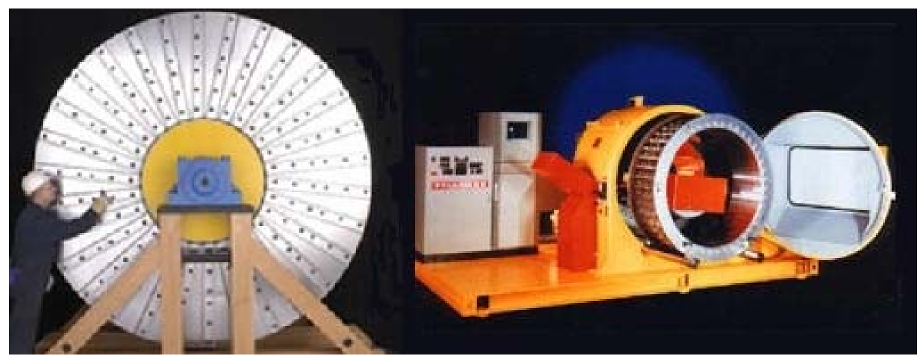
Hammer Hogs – non-cutting equipment

- Blunt tools pulverize wood at random until it passes through grates of a given size (Watson and Stevenson, 2007)
- Can handle a wide variety of inputs
- Produce many fines in the chips
- Very Large energy consumption (Watson and Stevenson, 2007)

Hammer Hog

Disc, drum and ring Flakers (Watson and Stevenson, 2007**)**

- Cut to Thin, Uniform, defined product size
- low production
- High capital and wear parts costs
- Many Use ‘batch’ log feed systems

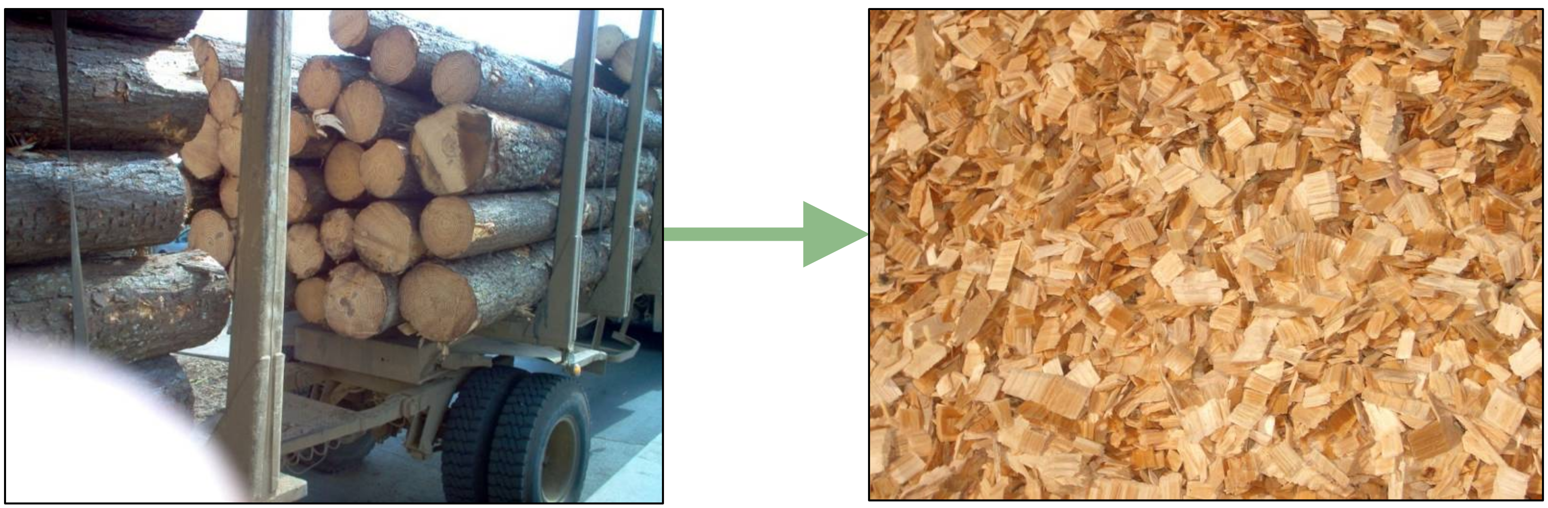


Disc and Ring Flakers

Wood Reducing Machines

Chip Producing Machines – continuous feed systems:

- Chunker (cone screw and involuted disc)
- Drum Chipper
- Disc Chipper and Disc Processor



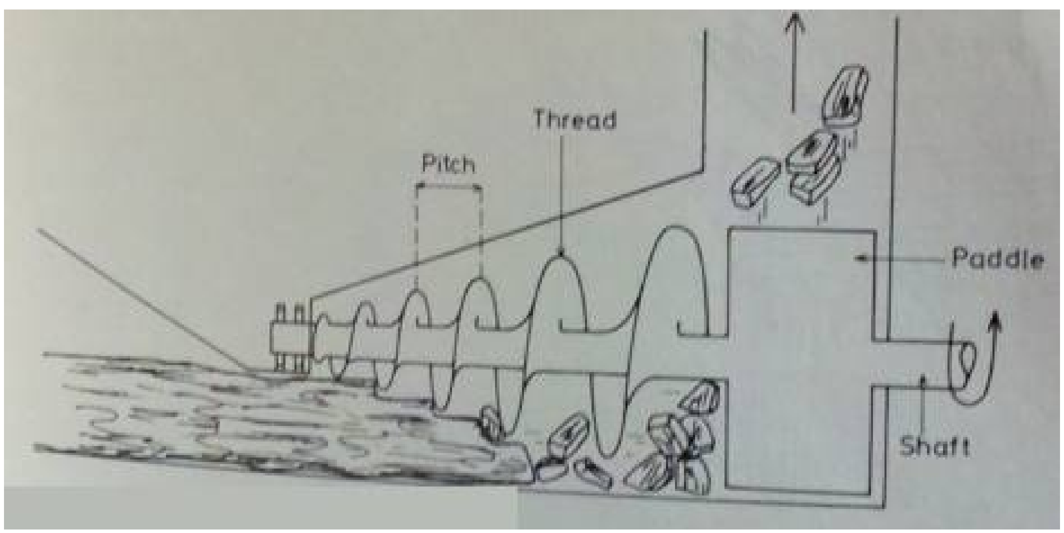
Logs before and after chipping

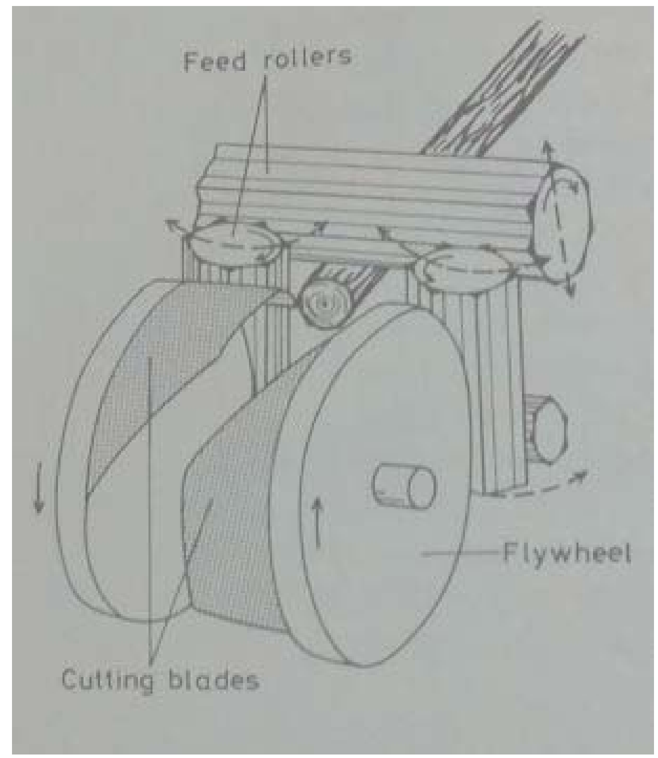
Wood Reducing Machines

Chunker

- Produces chunks of woods using disc blades or screw blades

Three-thread screw can chip wood at low production rates (Hakkila, 1989)





Wood Reducing Machines

Disc Chipper and Disc Processor

- High inertia rotating disc with many knives to produce uniform microchips (powered feed or self-feeding)
- Easily adjustable for a wide distribution of particle sizes for changes of season, wood species, moisture content, and chip size (Watson and Stevenson, 2007)
- Cuts uniform length microchips with low consumed energy due to a constant and ideal λ angle

Wood Reducing Machines

Disc Processor - a disc chipper with additional Patent Pending features that:

Permits improved self-feeding of logs in short-cut chip lengths

Efficiently cuts wood into significantly smaller sized chips than is possible in a normal disc chipper

Utilizes chipping energy that is normally wasted in order to more efficiently reduce chips to microchips.

Wood Reducing Machines

Disc Chipper and Disc Processor

- Commonly used for linear feed rates 0.5-0.7 M/sec (100-135 Ft/min)

2.95M (116”) CEM Processor for 650 mm (26”) dia Hdwds w/ 450 kW (600 HP) drive

Wood Reducing Machines

Disc Chipper and Processor

- …To linear feed rates over 1 M/sec (over 200 Ft/min)
- and capable of production rates over 300 TPH

Shown here in Price-LogPro Wood/Chip System

0.7 to 1 M (28”-39”) nom size feed spouts

Wood Reducing Machines

Disc Chipper (λ angle)

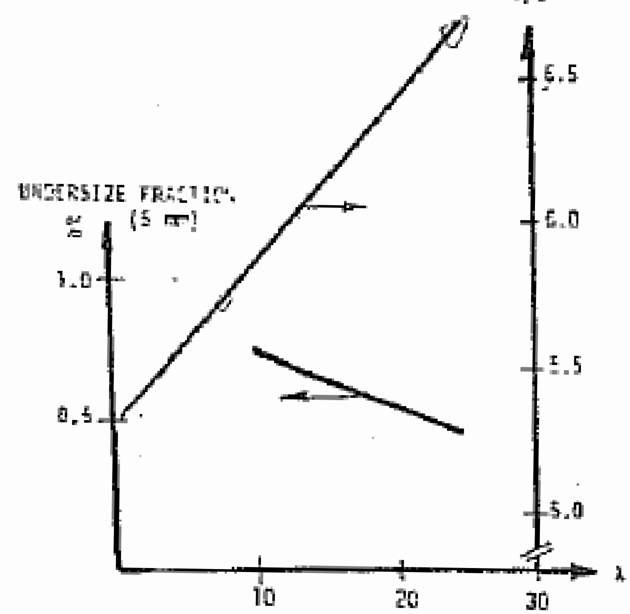
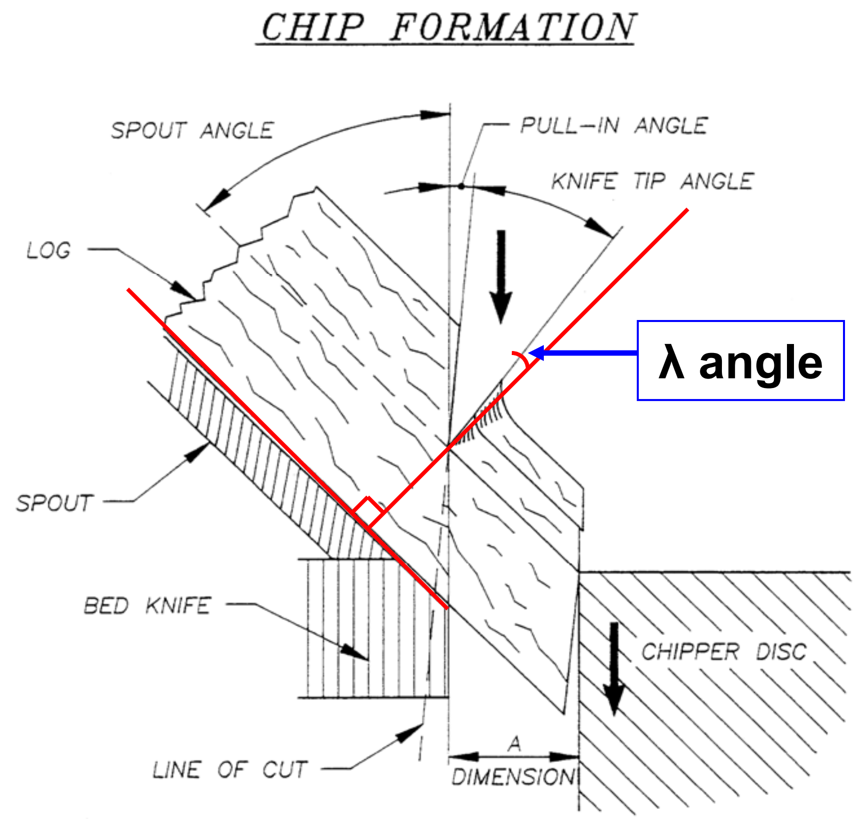


Fig. 10. Relationships between the undersize fraction (5 mm openings) and the chip length to thickness ratio and the angle λ = 90 - (ε + α + β). Data from (1,2).

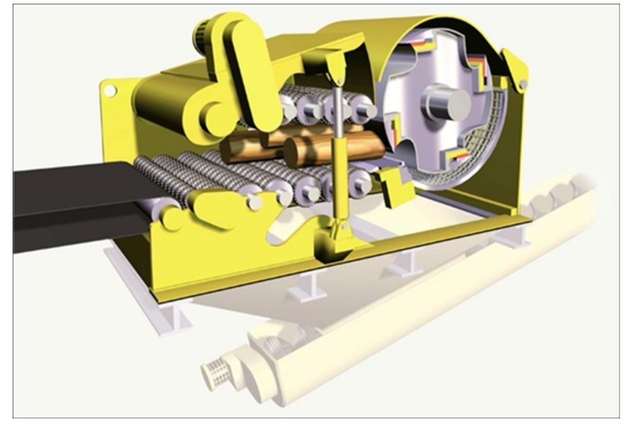


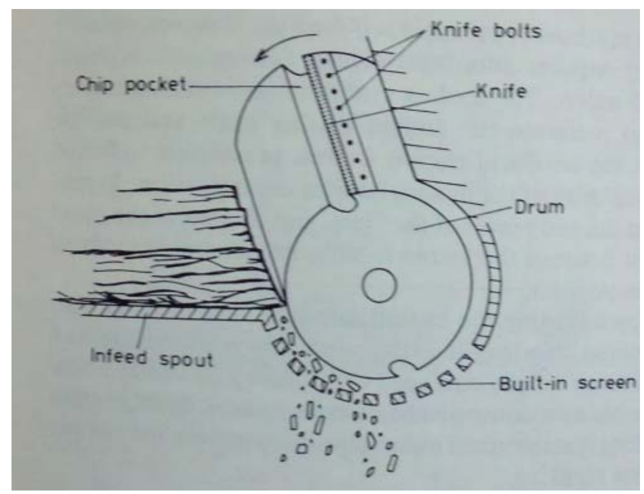
Note: Not optimal configuration of λ=14-18°

Wood Reducing Machines

Drum Chippers – also suitable for high productions

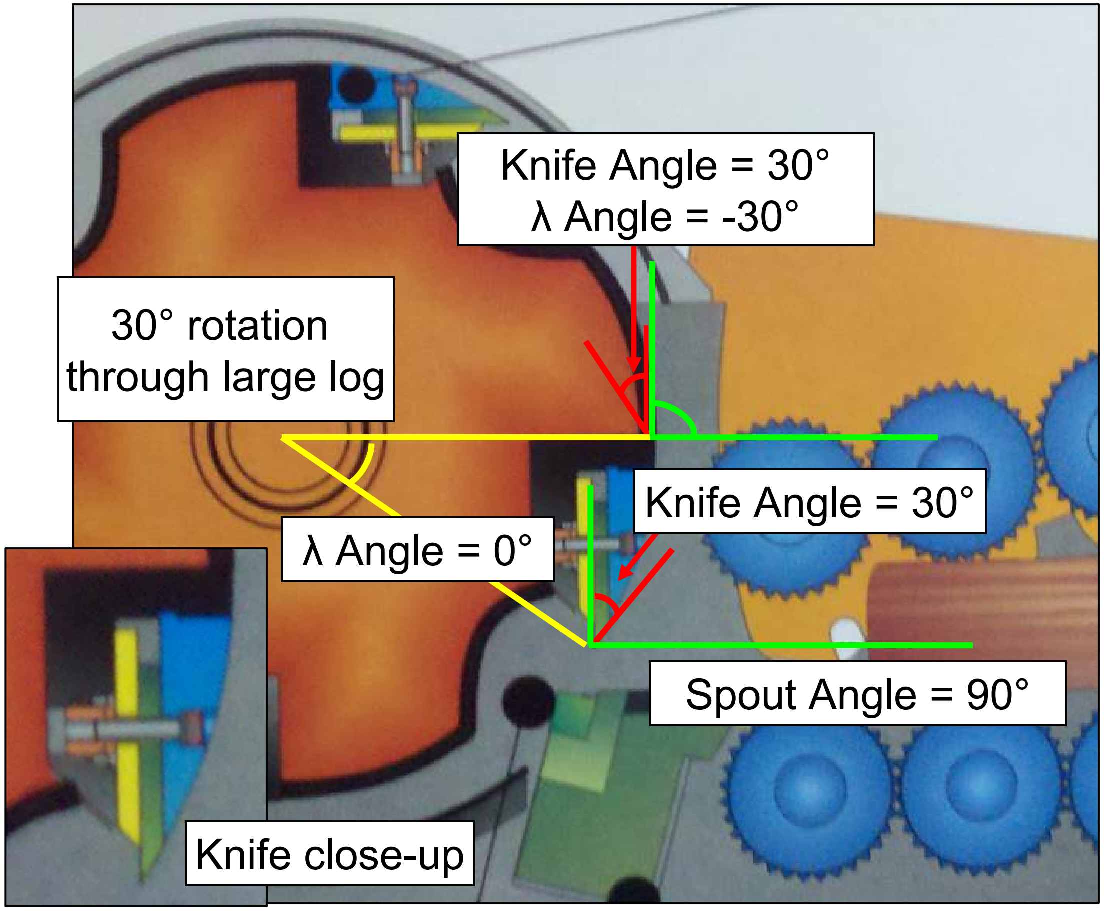
- Rotating drum with knives to produce small, relatively uniform wood particles (powered or self-feeding)
- Can easily reduce slash/limbed trees to chips (Hakkila, 1990)
- Compared to disc chipper or processor –
  - consumes more energy per unit of wood
  - chips are of a less uniformly cut length ('λ' angle varies)
  - grates/screens permit internally re-refining of chips to achieve a smaller overall microchip size, with more dust





Wood Reducing Machines

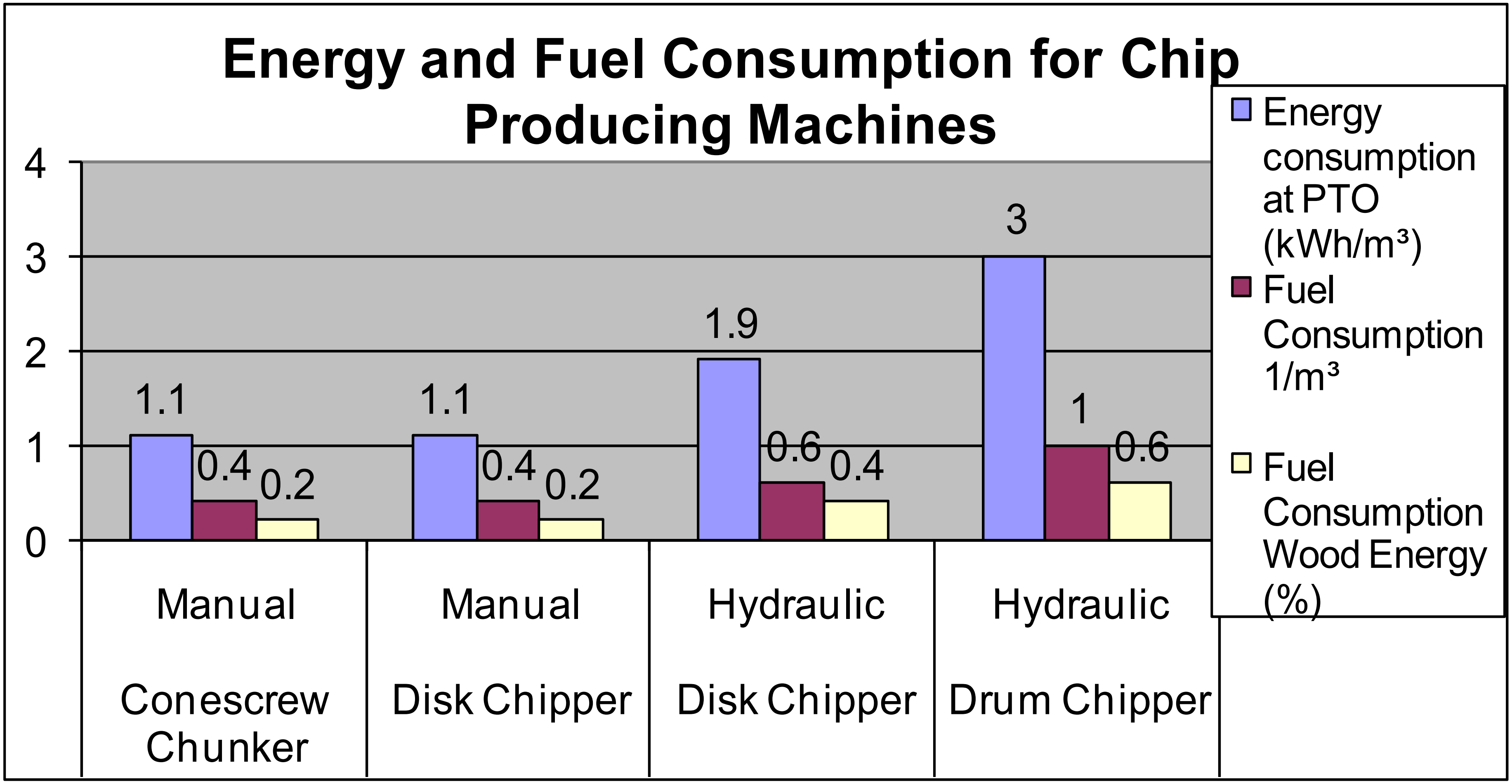
Drum Chipper (λ angle)



- λ angle changes from (-)30° to (+)15° during the entire cut of a large log (drum rotates 45°)
  - Note: 30° rotation shown at left
- Larger complimentary angle (λ) results in less force being required.
- Final λ similar to λ in optimal disc chipper/processor (14-18°)

Power Requirements for Wood Reduction

Data for Conventional sized chips – not microchips, not from a microprocessor



(Heikka and Piirainan, 1981)

Conclusions

- Microchips have a high specific area
    - Optimal for penetration, diffusion, expiration
- It is important for bioprocess plants to look at all biofuel (chip) parameters when setting up their processes
- High volumes of microchips can be produced by both drum and disc machines
    - With each machine type having its own characteristic advantages and disadvantages over the other.
- Microchips are a unique resource that could prove beneficial in many bioprocesses
    - Microchips are not the best for all biomass processes

References

1. Abdallah, R., Auchet, S., & Meausoone, P. J. (2011). Experimental study about the effects of disc chipper settings on the distribution of wood chip size. *Biomass and Bioenergy* , 843-852.
2. Bjurulf, A. (2006). *Chip Geometry.* Uppsala: Dept. of Forest Products and Markets.
3. Buchanan, J., & Duchnicki, T. (1963). Some experiments in low speed chipping. *Pulp Paper Mag. Canada* , 235-245.
4. Collyer, M. (2001). *Combustible Dust.* N.C. Dept. of Labor: OSHA.
5. Fahey, M. D. (1990). *Modified continuous Cooking for preparation of Kraft Pulp.* University of Washington: Kamyr, Inc.
6. Gustafson, R. et al, *The Role of Penetration and Diffusion in Pulping Nonuniformity of Softwood Chips*, 1988 TAPPI Alkaline Pulping Conference
7. Hakkila, D. P. (1989). *Utilization of Residual Forest Biomass.* Berlin: Springer-Verlag Berlin Heidelberg.
8. Heikka, T., & Piirainen, K. (1981). Power consumption of small chippers. *Fol For* , 496-518.
9. Mechanical Wood Products Branch, F. i. (1986). *Wood gas as engine fuel.* Rome: FAO.
10. Murto, J., & Kivimaa, E. (1951). Chipping of Pulpwood II. *Teoll Keskuslab Tied* , 66-68.
11. Nurmi, J. (1969). Chunking and chipping with a conescrew chunker. *Fol fur* , 659-682.
12. Robinson, MD (1989). Optimizing Chip Quality Through Understanding and Controlling Chipper Design Charactoristics and other variables. 1989 Pulping Conference TAPPI, 325-338.
13. Swithenbank, J., Chen, Q., Zhang, X., Sharifi, V., & Pourkashanian, M. (2011). Wood would burn. *Biomass and Bioenergy* , 999-1007.
14. Watson, W. F., & Stevenson, R. (2007). *The effect of seasonal variation in wood moisture content on chip size and Kraft pulping.* Atlanta: TAPPI.
15. Young, H., & Hatton, J. (1976). Chipping of tops and branches: a comparison of a drum and disc chipper. *Univ Maine Orono Res Life Sci* , 1-11.