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

(Mean size)

Legend:
- Drum Machine 1
- Drum Machine 2
- Drum Machine 3
- Disc Processor
- Disc Chipper

(Disc chipper data from Robinson, 1989)

(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:
\[ V_{\text{conv}} = L \times W \times T \]

Microchip main dimensions are halved, so microchip volume:
\[ V_{\text{micro}} = 0.5L \times 0.5W \times 0.5T \]
\[ = 0.125 \times L \times W \times T = 0.125 \times V_{\text{conv}} \]

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

Surface Area per Volume Ratio
- 10 mm Chip - 1.2:1
- 20 mm Chip - 0.6:1

Microchip has twice the specific area of a conventional chip

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 $\rightarrow$ faster penetration
- Chemical processes such as pulping depend on smallest dimension (Hakilla, 1989)
- Raising pH increases penetration rates (Higher alkalinity $\rightarrow$ 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
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” (Swithinbank et al, 2011)

• A microchip has a greater expiration rate
  • Every 10% moisture increase reduces CV (caloretic value of fuel) by 2 MJ/kg (Swithinbank et al, 2011)
Process characteristics of microchips in pellets

**Mechanical Biomass Processes**

- Smaller wood particles reduce more efficiently

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

![Pie chart showing energy distribution]

- 61%: Energy to reduce from whole air dry hardwood logs to microchips
- 23%: Additional Energy for all product to pass through wet hammer mill w/ 12 mm grate
- 16%: Additional Energy for all product to pass through a dry hammer mill w/ 6 mm grate
Microchip Power Consumption

The effect of particle length on energy consumption in a disc chipper

(Murto & Kivimaa, 1951)

10 mm Chip - 1.95 kWh/m³
20 mm Chip - 1.1 kWh/m³
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.
Reduced grinding energy of Torrefied chips

Results – Grinding Energy

Sudhagar Mani, UGA, IBBC 2011
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 once dried below 10% M.C.
• 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 their chips
- Very Large energy consumption (Watson and Stevenson, 2007)

**Disc, drum and ring Flakers** (Watson and Stevenson, 2007)
- Cut to Thin, Uniform, defined product size
- Low production (mostly all cutting)
- High capital and wear parts costs
- Many Use ‘batch’ log feed systems
Wood Reducing Machines

Chip Producing Machines – continuous feed systems:

- Chunker (cone screw and involuted disc)
- Drum Chipper
- Disc Chipper and Disc Processor
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 Chips or microchips with low consumed energy due to a constant and ideal \( \lambda \) 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”) nominal size feed spouts
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 (‘\(\lambda\) angle varies)
  - grates/screens permit internally re-refining of chips to achieve a smaller overall microchip size, with more dust
Wood Reducing Machines

Disc Chipper ($\lambda$ angle)

Note: Not optimal configuration of $\lambda=14-15$
Wood Reducing Machines

Drum Chipper (\(\lambda\) angle)

- \(\lambda\) 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 (\(\lambda\)) results in less force being required.
- Final \(\lambda\) similar to \(\lambda\) in optimal disc chipper/processor (14-15°)

Knife Angle = 30
\(\lambda\) Angle = -30  

Knife Angle = 30
Spout Angle = 90

\(\lambda\) Angle = 0

30 rotation through large log

Knife close-up
Effect of complementary angle on work required

- J Buchanan and T Duchnicki, 1963
Effect of complementary angle on chip formation and chip thickness

- J Buchanan and T Duchnicki, 1963 (3)
Effect of complementary angle on work required

- J Buchanan and T Duchnicki, 1963 (3)

Fig. 1. Force record for dry wood.
Effect of complementary angle on work required

EACH $10^\circ\lambda$ decrease from $26^\circ$ results in a 20-30% increase in work.

J Buchanan and T Duchnicki, 1963 (3)
Power Requirements for Wood Reduction

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

Energy and Fuel Consumption for Chip Producing Machines

- **Manual Conescrew**
  - Energy: 1.1 kWh/m³
  - Fuel Consumption: 0.4 l/m³
  - Wood Energy: 0.2%

- **Manual Disk Chipper**
  - Energy: 1.1 kWh/m³
  - Fuel Consumption: 0.4 l/m³
  - Wood Energy: 0.2%

- **Hydraulic Disk Chipper**
  - Energy: 1.9 kWh/m³
  - Fuel Consumption: 0.6 l/m³
  - Wood Energy: 0.4%

- **Hydraulic Drum Chipper**
  - Energy: 3 kWh/m³
  - Fuel Consumption: 1 l/m³
  - Wood Energy: 0.6%

(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


Table 002-4.2 Tabulation of horsepower-hours per cord for various wood species
(85 cubic feet of wood in a stacked cord)

<table>
<thead>
<tr>
<th>Species</th>
<th>Shear stress psi</th>
<th>Recommended hp-hr/cord</th>
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<tbody>
<tr>
<td>Fir</td>
<td>690</td>
<td></td>
</tr>
<tr>
<td>Balsam</td>
<td>690</td>
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</tr>
<tr>
<td>Aspen</td>
<td>800</td>
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<tr>
<td>Spruce</td>
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<td></td>
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<tr>
<td>Poplar</td>
<td>980</td>
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</tr>
<tr>
<td>Pine-Northern</td>
<td>800/1040</td>
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</tr>
<tr>
<td>Hemlock</td>
<td>1010/1060</td>
<td></td>
</tr>
<tr>
<td>Larch</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>Pine-Southern</td>
<td>1180/1350</td>
<td></td>
</tr>
<tr>
<td>Gum</td>
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<tr>
<td>Maple</td>
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<tr>
<td>Tropical Hardwoods&lt;sup&gt;a&lt;/sup&gt;</td>
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<sup>a</sup>Recommended power for these species has been increased as the result of operating experience.

<sup>b</sup>Some species have shown power requirements in excess of 15 hp-hr/cord. Care should be exercised in sizing motors for such application.

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CEM finds these Tappi factors to be about 30% conservative for chippers configured as CEM does

THIS TAPPI factor for SYP is about 30% LESS than the factor CEM used to size the German Pellets processor.