Bachelor Thesis

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Guide to Biomass comminution

material properties, machinery, principles of the process and fundamentals of process modelling

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Material properties, machinery, principles of the process and fundamentals of process modelling
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1. INTRODUCTION

1.1 General

Comminution is a process in which solid materials are reduced in size. Fibre is a morphological term for a substance characterised by its high ratio of length to cross sectional area, fineness and flexibility.

Fibrous material is that kind of material that consist of fibres. In most of the cases fibrous materials that are being comminuted are composite materials. These are the materials that consist of two or more constituent materials which have significantly different properties and remain separate and distinct within the structure. Properties of the composite material are determined not only by the constituents, but also by the way that they are combined.

Comminution of fibrous materials has many different applications. Usually comminuted fibrous materials are of biological origin. Main reason for comminution is to enable bigger surface of comminuted materials necessary for further processing.

The most common applications are:

- Food industry - comminution of food in order to enable highest possible surface of ingredients in order to perform the most efficient and effective reaction between them. It should be mentioned that eating process itself also starts with a comminution. People chew food to enable new surface for digestion enzymes. Most of the people had an opportunity to find out how does digestion reaction proceed in their stomach if they do not chew food properly (especially one that is hard to digest).
- Pulp and paper industry - paper is made of cellulose fibres from ligno-cellulosic biomass (wood). The goal is to keep the fibres unharmed as much as possible. Though they need to be separated from hemicelluloses and lignin. In order to make that separation possible, by chemical and thermal reaction or mechanical actions, more surface has to be enabled for the process.
- Particleboard industry - comminution is made both in order to get the new surface for adhesives, and to achieve relatively uniform size of the particles.
- Bioenergy - comminution is important in order to enable new surface either for biofuel upgrade like gasification (conversion via chemical reactions) or for better and more complete combustion (combustion is also a chemical reaction). It's also necessary for other type of fuel upgrade - pelletizing. It's a physical process and in general it's about biomass compaction. To make compaction possible structure needs to be broken down first.

This study focus mainly on woody biomass comminution for Bioenergy applications.

According to (I. M. Petre, 2006) there are three distinguished results of biomass comminution:

a) particle sizing and classifying (coarse and intermediate size reduction)
b) particle shaping
c) breaking connections between different material components

1.2 Comminution as one unit operation in the Biofuel supply chain

When biomass is used as an energy source in most of the cases comminution is necessary. It is possible to use biomass in the forms of the full logs, and it has been done in a small scale home appliances. But because of the low efficiency and other problems like high level of CO and volatile emissions it’s definitely not recommended option.

It’s justified to say that comminution is placed in biofuel supply chain and it’s always placed in-between biomass harvest and combustion stage. As previously stated some form of comminution is necessary to achieve efficient combustion. It goes well with common sense because combustion is a chemical reaction and comminution enables new surface for that reaction to happen so achieving better efficiency of the reaction is totally logical conclusion.

In general any other operations between biomass harvest and utilisation are aiming in enabling biomass to be used by the technology of the device where biomass is utilised - mostly boiler. The goal is to utilise it in the most efficient way. Combustion reaction seems to be quite simple when one uses macroscopic approach and analyses input and output only, without detailed look into things that happen inside reactor - namely combustion chamber. To make reaction happen two reactants must be at hand - fuel and oxygen. Both need to be delivered into reactor in a way that allows to control amount of both in order to control the reaction.

To make it work proper feeding mechanism is necessary. That’s the main place in the supply chain where comminution is necessary. Size of output material has to be adjusted to the feeding mechanism - utilising device technology. In case when next stage of supply chain is not combustion but for example densification of biomass, in order to make transportation more efficient by f. ex. pelletizing, same general rule applies. It’s because pelletizer has acceptable size range for biomass particles and only within that range can work properly.

On the other side of the comminution as an operation there is input size of the material. That depends highly on technology of the comminution device itself and would be a subject of more detailed discussion in further chapters of this study.

It’s possible that size difference between material from the first operation (harvest) and final operation is too big and more than one operation of comminution needs to be introduced because there is no suitable comminution device that can handle that difference singlehandly. There is also a possibility that second stage of comminution is introduced separately in order to use residues from the main process (*Fig. 1.1*).

In general no operation is 100% efficient and there are always residues available. Residues are present at basically every stage - even harvesting. Ratio of residues to output material is very operation dependent. In some cases amount of residues is big enough to make usage of those residues profitable.

It seems necessary to mention that the need of comminution might not be determined by purely technical issues. Sometimes comminution is chosen only to introduce residues into existing technology and is a cheaper substitute for right choice of the final utilisation unit in order to reduce the investment cost.

Figure 1.1 - Example of placing comminution operations in supply chain (L.J. Naimi, 2006)

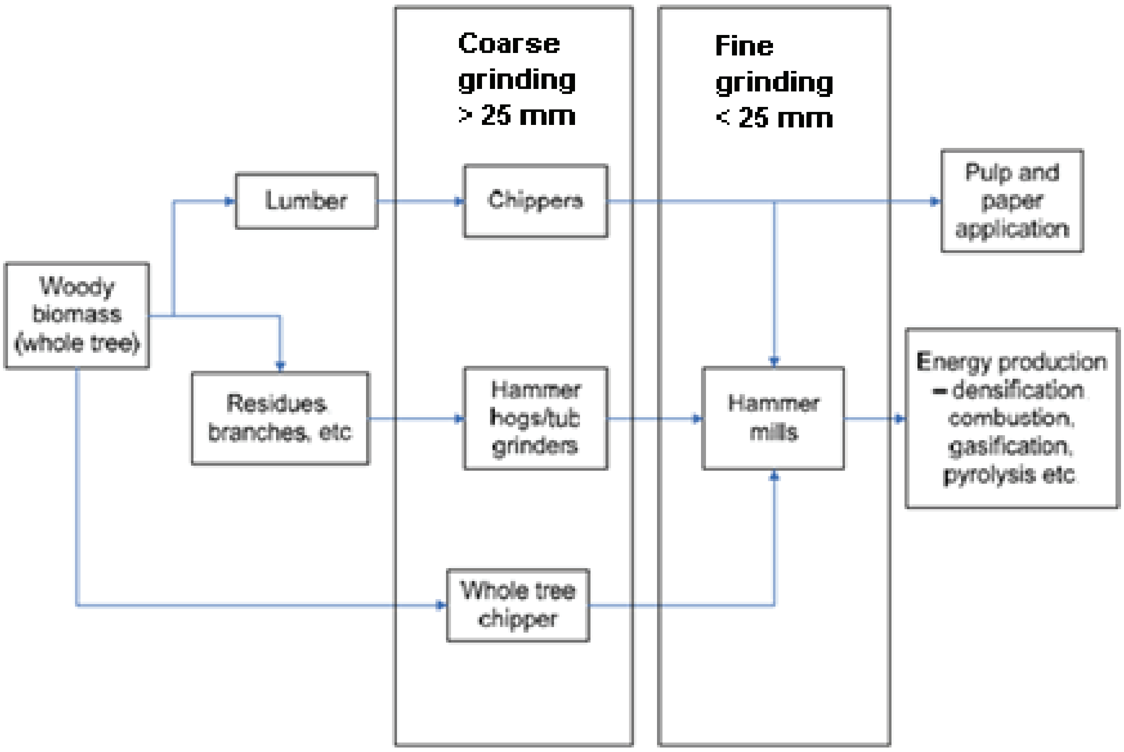

Table 1.1 - Different type of devices utilising biomass with respect to the input material requirements (L.J. Naimi, 2006)

	Pile burners (wet cells)	Thin-pile Spreader-stoker	Under-fire Stokers	Suspension, cyclonic	Suspension, air Spreader-stoker	FBCs (Fluidized bed combustors)	Gasifiers, Fixed bed	Gasifiers, FBG
Device size range	Up to 40 GW_t			1.5MW-3 GW_t		15-900 MW_t	17 MW_t- 24 GW_t	2.5-50 MW_t
Comment	Virtually any kind except wood flour	Sawdust, non-stringy bark Shavings, end cuts, chips and chips rejects, hog fuel	Sawdust, Non-stringy bark shavings, chips, hog fuel	Sawdust, non-stringy bark, shaving, flour, sander dust	Sawdust, non-stringy bark, shavings, flour, sander dust, hog fuel	Virtually and kind except wood flour and stringy materials	Chip, hog fuel	Virtually any kind except wood flour and stringy materials
Particle size	Limited by grate size and feed opening	6-50 mm	6-38mm	6mm max	6mm max	50mm max	6-100mm	6-50mm
Moisture Content	<65%	10-50%	10-30%	<15%	10%	<60%	<20%	15-65%

Table 1.1 shows some examples of input material size and properties for different devices. It shows high variability in terms of the acceptable input size. Other thing it shows is high variability in required moisture content. That means the drying as an operation in supply chain could also be present. That also indicates that biomass is highly variable material generally speaking.

One of the main question this study aims to answer is an existence of qualitative way to determine possibility to optimize biofuel supply chain by lowering energy consumption during the comminution stage.