Chapter 1

Modeling Size Reduction and Fractionation for Cellulosic Feedstock

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ABSTRACT

Biomass has attracted attention as a source of renewable energy. It is available in different forms such as lignocellulosic stalks of herbaceous and woody biomass. These forms of biomass should be prepared to go through bioconversion process or biofuel production. One of the major unit operations for preparation is size reduction, which increases the surface area available and breaks the structure of biomass. Size reduction is energy intensive and an expensive step of feedstock preparation. The characteristics of ground particles are the result of interactions between material properties and the modes of size reduction like shear, impact, and attrition. The fundamentals of size reduction of fibrous biomass are not well understood. This chapter summarizes the latest studies on modeling of size reduction of lignocellulosic and woody biomass.

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INTRODUCTION

The form of biomass and the nature of end processes have a major impact on the selection of equipment, thus making design and selection of efficient equipment a challenge for engineers.

Woody biomass can be available in the form of logs and logging residues, sawdust and shavings, or short rotation fast growing trees. Logging residues consist of different parts of trees such as branches and leaves. Sawdust and shavings are often leftovers from wood working operations. Examples of short rotation trees include willows and poplars, all of which have a high rate of growth and can be harvested in a short time. Bulk density increases during grinding. This increase has major impact on transportation efficiency. In most grinding scenarios, the first step of size reduction happens in field to produce material with higher density and improve transportation efficiency. Esteban and Carrasco (2006) reported that initial bulk density of poplar chips and pine chips was 148.75 kg/m³ and 258.25 kg/m³, respectively. Bulk density of poplar chips and pine chips increased to 225.64 kg/m³ and 328.76 kg/m³, respectively, after grinding.

Lignocellulosic stalks (also known as herbaceous biomass) come from agricultural residues like corn stover, wheat straw, rice, and cotton. The stalks can also come from crops like switchgrass, miscanthus, giant reed and sorghum. These crops are cultivated for a specific application like bioenergy or feedstock for animal bedding.

Size reduction of biomass often occurs in more than one step, depending on the final use of ground biomass. The position of the steps of size reduction in the sequence of preparation processes of biomass for downstream process can have a major impact on the cost of preparation. Sokhansanj and Turhollow (2004) reported that moving the grinding operation to the field reduces the cost of cubing of grasses and stover.

Previous studies show woody and herbaceous biomass require different energy input during grinding. Each species differs in mean and distribution of size when ground in the same grinder set up (Mani, Tabil, & Sokhansanj, 2004; Esteban et al., 2006; Bitra et al., 2009; Adapa, Tabil, & Schoenau, 2011). Factors such as moisture content, input particle size, and mechanism of grinding affect size reduction energy consumption.

Every conversion process needs its specific biomass particle size to operate efficiently. The effects of particle size on various conversion processes are discussed in the following section.

Size reduction equipment are designed with a versatility such that to grind a wide range of feedstock for which little physical properties are known. Dimensions of biomass and its moisture content can be measured and somewhat controlled for
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