Rotary Equipment and Process Investigation for Biomass Size Reduction

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Introduction

Background

Two primary research pathways for developing bio-based products are:

- Feedstock supply logistics that includes material handling, size reduction, drying and storage
- Particle fragmentation and separation that isolate target constituents to improve subsequent bioconversion processes

Statement of the problem

- Feedstock handling and bioconversion processes require different degrees of biomass size reduction
- Very little is known about comminution process of fibrous bio-materials and their interactions with grinding equipment
- Size reduction processes optimization is required

Objectives

- Analysis of experimental data obtained from the testing of different equipment
- Analysis of existing design of rotary equipment
- Explore new design ideas of rotary equipment
- Analysis of size reduction processes performed by selected equipment

Size reduction advantages

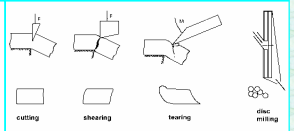
- Easy handling and drying of bulk material
- Initial densification (to a certain extent)
- Facile densification through subsequent processing (briquetting, pelleting)
- Reduced costs of transportation
- Facile sorting of material by size through separation
- Increased reactive surface area of biomass particles, which are exposed to bio-chemical processing

Size reduction

Biomass size reduction refers to mechanical treatment processes that significantly change the particle size, shape and bulk density of the material. These processes may involve one or a combination of the following types of actions: *cutting, shearing, tearing, impact stress, compression and friction.*

Comminution effects

- Particle sizing and classifying
- Particle shaping
- Breaking connections between different material components

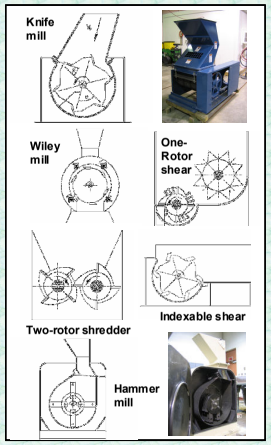


Types of actions & particle shape

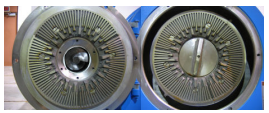
Two-rotor shredders

Four-rotor shredders

Equipment Type	Description	Clearance	Specifications
Rotary cutters	Knife mill	Radial gap	4-8 cutterhead knives Knife rake angle Knife helix angle
	Wiley mill	Radial gap	4-6 cutterhead knives 4 stationary or counterhead knives
Rotary shears	One-rotor shear	Axial gap	
	Two-rotor shear		
	Indexable Knife shear	Radial gap	
	Block knife shear		
Rotary shredders	Swing-hammer mill	Radial gap	4-8 rows with knives
	Shredder with pins		
	Shredder with knives	Axial gap	
	Shredder w/ toothed slats		



Material Type Variety	Initial / Final size, mm	Moisture content, % w.b.	Equipment	Equipment Specs	Bulk / Particle Density, kg/m³	Required Processing Energy kwh/t	Authors / Comments
Switch-grass	Bale / 25-100 25-100 /	7.5-10.3	-Chopping - Fine grinding	N/A 2.78 mm sieve opening 5.6		14.90 55.90 74.50	Jonasch
						44.90	Samson, 2000
Switch-grass	/ 0.794	8	Hammer mill			62.62	Mani et al. 2002
	/ 1.588					51.83	
	/ 3.175					23.50	
	/ 0.794	12				55.63	
	/ 1.588					58.57	
	/ 3.175					27.17	
Corn-stover	/ 0.682	7		6.35 mm	111.7/1085		Mani et al. 2003
	/ 0.407			3.18 mm	130/1210		
Corn-stover	7.15/0.794	6.2				22.07	Mani et al. 2002
	7.15/1.588					14.79	
	7.15/3.175					6.96	
	7.15/0.794	12				34.30	
	7.15/1.588					19.84	
	7.15/3.175					11.04	
Corn-stover	/ 1.6		Knife mill			14.00	Cadoche & Lopez, 1989
	/ 3.2					9.60	
	/ 3.2					20.00	
	/ 6.35					15.00	
	/ 9.50					3.20	
Wheat straw	7.67/0.794	8.3	Hammer mill			51.55	Mani et al. 2002
	7.67/1.588					39.59	
	7.67/3.175					10.77	
	7.67/0.794	12				45.32	
	7.67/1.588					43.56	
	7.67/3.175					24.66	



Active plates of a disc mill

Acknowledgements

- U.S. Department of Energy
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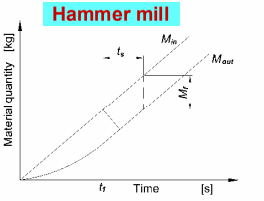
Size reduction processes

Knife mill

Particle average size:

$$\delta_m = \frac{2\pi}{3}\frac{v_F R}{vz}$$

Hammer mill



Operation diagram

Closed circuit grinding