LINEAR EQUIPMENT AND PROCESS INVESTIGATION FOR BIOMASS SIZE REDUCTION

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BACKGROUND

- Linear size reduction equipment use shearing as the major size reduction action, which is the most efficient mode of failure for biomaterials
- Linear cutting actions are more direct, hence efficient transfer of input cutting energy from the equipment to biomass
- Size reduction methods using linear knife grid serve as preprocessing step to the intended fine products
- Linear size reduction equipment prototypes can be easily evaluated in universal testing machine

OBJECTIVES

1. Evaluation of size reduction characteristics of single stalk of biomass using modified Warner-Bratzler shear device
2. Evaluation of size reduction characteristics of biomass stalks using the developed linear knife grid device

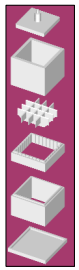
DEVICE DESCRIPTION

Modified Warner-Bratzler Shear Device:

- The blunt blade of this standard shear testing device was modified to a sharp tool steel blade with cutting edge having 30° bevel angle

Developed Linear Knife Grid Device:

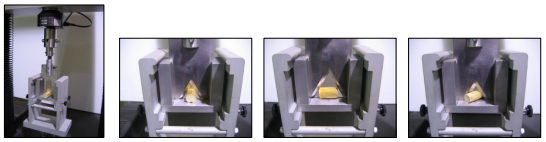
- Major components are ram, feed block, knife grid, knife holder block, product block, and bottom tray
- Knifes arranged in a square grid pattern using detachable cross-lap joints
- Whole assembly can be mounted and tested on a universal testing machine
- Knifes are protected by foam pad between ram and sample



TEST MATERIAL

Crop:	Corn – Var. Gamecorn (Developed by the UT breeding program for wildlife food plots)
Planting date:	April 21, 2005
Ear harvest:	October 5, 2005
Stalk harvest:	December 7 and 14, 2005
Moisture content:	15 to 20% w.b.

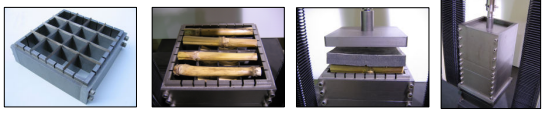
EXPERIMENTAL – Warner-Bratzler



Complete device | Stalk axis perpendicular | Stalk axis parallel | Stalk axis 45° inclined

Modified Warner-Bratzler device testing corn stalks

EXPERIMENTAL – Linear knife grid

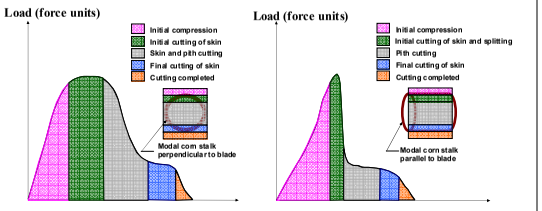


Knifes at 2″ spacing | Corn stalks on knife grid | Foam pad protection | Complete assembly

Developed linear knife grid device testing corn stalks

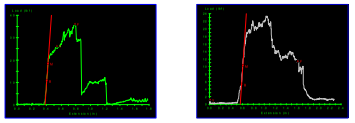
RESULTS – Cutting of corn stalk

Corn stalks after cutting on knife grid | Cut product on bottom holder | Industrial scale knife grid for biomass

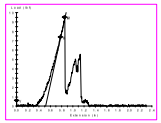


Typical cutting characteristics curves of corn stalk using Warner-Bratzler device

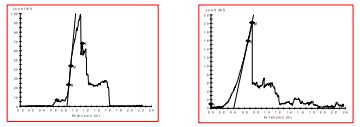
RESULTS – Warner-Bratzler



Internode: Stalk axis perpendicular to blade | Internode: Stalk axis at 45° to blade



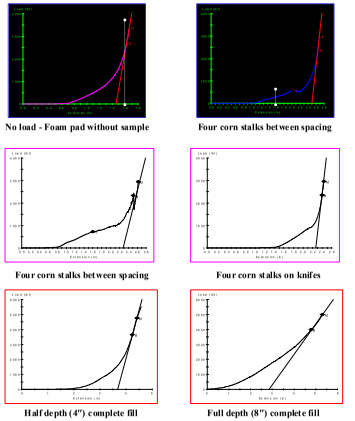
Internode: Stalk axis parallel to blade



Node: Stalk axis perpendicular to blade | Node: Stalk axis parallel to blade

Examples of load-deformation characteristics using Warner – Bratzler device

RESULTS – Linear knife grid



No load - Foam pad without sample | Four corn stalks between spacing

Four corn stalks between spacing | Four corn stalks on knifes

Half depth (4″) complete fill | Full depth (8″) complete fill

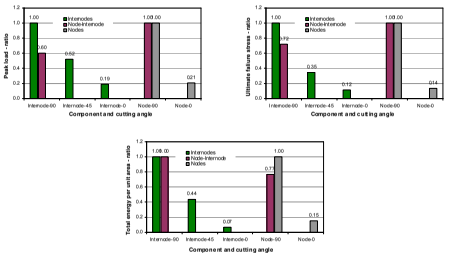
Examples of load-deformation characteristics using linear knife grid device

RESULTS – Warner-Bratzler corn stalk cutting

Summary of Warner – Bratzler results for corn stover

Test details	Dim 2a mm	Dim 2b mm	Peak Load N	Energy (Nm) Break	Energy (Nm) Peak	Energy (Nm) Total	Area Generated m²	Ultimate Stress MPa	Energy /area Nm/m²
Internode – Perpendicular to stalk axis									
Average	19.89	18.02	244.57	3.10	2.46	4.97	2.99E-04	0.86	15242
Std. dev.	5.35	4.34	133.54	2.71	2.01	4.12	1.49E-04	0.28	7390
Node – Perpendicular to stalk axis									
Average	21.49	19.19	407.70	3.02	1.87	4.69	3.49E-04	1.20	11684
Std. dev.	6.37	5.40	227.59	5.21	1.68	6.03	1.95E-04	0.41	7415
Internode – Parallel to stalk axis									
Average	21.52	19.30	46.54	0.24	0.24	0.48	4.84E-04	0.10	998
Std. dev.	5.06	4.23	14.29	0.08	0.08	0.14	1.08E-04	0.03	218
Internode - 45° inclined to stalk axis									
Average	28.73	19.05	127.01	2.37	1.19	2.99	4.42E-04	0.30	6636
Std. dev.	5.17	3.39	37.99	1.28	0.69	1.49	1.69E-04	0.07	1694
Node – Parallel to stalk axis									
Average	26.23	21.05	83.89	0.44	0.44	0.93	5.40E-04	0.16	1782
Std. dev.	5.74	4.01	23.61	0.10	0.10	0.13	1.04E-04	0.05	384

UTM Crosshead speed: 2.5 inch/min; Moisture content of stalks: 15-20% w.b.



Comparison of results among corn stalk components and cutting blade movement with respect to the stalk axis

CONCLUSIONS

- Four regions on the load-deformation curve such as initial compression, initial cutting of stalk skin at peak loads, continued skin and pith cutting, and final skin cutting were observed with corn stalks
- Based on internodes and nodes, cutting across the fibers takes approximately 6.5 times more effort than cutting along the fibers in the direction of stalk axis
- A 45° inclined cut requires around 2.3 times more effort than cutting along the stalk axis direction (0°)
- Peak failure load of nodes was approximately 1.7 times larger than that of internodes
- As bioconversion processes kinetics are proportional to the biomass reaction surface generated, the size reduction operation involving increased cutting along the fiber tend to be highly energy efficient