MECHANICAL PROPERTIES OF BROOMCORN STALK IN RELATION TO QUASSI-STATIC LOADING AS A FUNCTION OF MOISTURE CONTENT

Hossein Ghaffari, Mehdi Shirazi*, Ne'man Marghoub
* Corresponding author: Tel: +989352554458 E-mail: mehdishirazi1390@yahoo.com

Abstract

Experiments were conducted to study the effect of moisture content, shearing speed and orientation on shearing force, strength, energy and specific energy of three genotypes of broomcorn stalk. The specific shearing energy and shearing strength obtained by dividing them by cross sectional of stalk. The results showed that, the amount of shearing force, strength, energy and specific energy were increased by increasing moisture content and cutting orientation when changed from parallel (0°) to perpendicular (90°).

Keywords

Shearing force; Shearing strength; Shearing energy and specific energy; Broomcorn

Introduction

Broomcorn (Sorghum vulgare (L.) Moench var. technicum) is a very strategic plant in Miyaneh region located in the north west of Iran. It is planting frequently due to the high economic benefits, mostly with no crop shifting (Jamshidi et al., 2011). Several tons of stalks are produced from this crop annually. These stalks usually used for feeding of animals and mostly the broom can be produced from it. For these reason, stalks must be processed after harvesting. It is necessary to know the mechanical properties of Broomcorn stalk, for designing equipment related to harvesting and postharvesting operations.

In shearing process, the shearing tools with overcoming the shearing strength make apart the product. According to the shape of shearing tools, there are different reactions, for this reason, it is cannot be discussed in general without specifying how objects cut and move.

Taghijarah et al. 2011, determined the effect of loading rate and internode position on shearing characteristics of sugar cane stalk. Their experiment were conducted at three loading rates of 5, 10, and 15 mm/min and at the ten internode positions down from the flower and then the following equation was used to obtain the shearing strength:

\[ \tau_s = \frac{F_s}{2A} \]  

(1)

Where: \( \tau_s \) is the shear strength (MPa), \( F_s \) is the shear force at failure (N) and \( A \) is the wall area of the specimen at the failure cross-section (mm²). The shearing energy, \( E_s \), was calculated by integrating the area under curves of shear force and displacement using a standard computer program. The specific shearing energy, \( E_{sc} \) was calculated by dividing shearing energy by wall area of the specimen at the failure cross-section.

Igathinathane et al. 2010, selected corn stalk at 15 to 20% wet bases for their study. They studied orientation effect on mechanical cutting. To evaluate the mechanical cutting characteristics of corn stalks, a Warner - Bratzler device
was modified by replacing its blunt edged cutting element with one having a 30˚ single bevel sharp knife edge. Cutting force-deformation characteristics obtained with a universal testing machine were analyzed to evaluate the orientation effects at perpendicular (90˚), inclined (45˚), and parallel (0˚) orientations on internodes and nodes for cutting force, energy, ultimate stress, and specific energy of corn stalks.


This study has been done due to lack of information about the mechanical properties of broomcorn stalk for using to design harvest and postharvest machines.

**Material and methods**

The purpose of the study was to evaluate the effect of three genotypes of broomcorn (SHY, GAL and KAF), moisture content, shearing speed and stalk orientation (parallel (0˚) orientation and (90˚ and 45˚) orientations) on the shearing force, strength, energy and specific energy.

The broomcorn stalk samples were prepared by stripping of the leaves and husks. The moisture content of the prepared stalks was 12 and 65% that 12% moisture content used to prepare broom and 65% is harvesting moisture content (ASABE Standards, Sec. 358.2, 2008). The cross section profile of the stalks assumed to be a circle. The dimension of stalk was measured prior to testing using digital calliper.

A universal Hounsfield machine (H5KS) was used as the measurement platform in combination with the modified shearing tool with 45˚ oblique angle with jagged edge. Qmat 3.96 software controlled the Hounsfield machine and acquired the data. A quasi-static cutting speed of 10, 50 and 100 mm/min, was controlled by the cross head movement of the Hounsfield machine. The shearing tool attached to the crosshead moved down during cutting and the stationary support block was attached to the bed of the set.

The Qmat software was preprogrammed to directly output the peak load and total energy from the force-displacement characteristics. From these results, the ultimate cutting stress and specific energy were calculated from the cut sectional areas as Eq. 1 and Eq. 2:

\[ E_{sc} = \frac{E_s}{A} \]  

Where: \( E_{sc} \) is the specific shearing energy (\( j/m^2 \)), \( E_s \) is shearing energy (\( j \)) and \( A \) is cross section area (\( m^2 \)).

The study was planned as a completely Randomised design and there were three replications in each treatment. Experimental data were analyzed using analysis of variance (ANOVA) and the means were separated at the 5% level applying Duncan’s multiple range tests in SAS (ver. 9.1) software.

**Results and discussion**

**Shearing force**

The force required to cut the stalk is shearing force. ANOVA results showed that the effects of moisture content and orientation were significant at 1% probability level. The shearing force increased by increasing moisture content (Fig 1). Similar results were reported for maize stalk (Chen et al. 2007), pyrethrum stem (khazaei et al. 2002), sesame stalk (Yilmaz et al. 2009) and alfalfas stem (Nazari Galedar et al. 2008). A very clear reduction of force was observed when the cutting orientation changed from perpendicular (90˚) to parallel (0˚). The stalk of broomcorn is
fibrous and the shearing strength in parallel position is as less as perpendicular. So that Igathinathane et al. 2010, was reported similar result for corn stalk.

![Graph](image1)

**Fig. 1:** The effect of three genotypes of broomcorn (SHY, GAL and KAF), moisture content, shearing speed and stalk orientation (parallel (0°) orientation and (90° and 45°) orientations) on the shearing force

**Shearing strength**

ANOVA results of shearing strength showed that the effects of moisture content and orientation were significant at 1% probability level and the effect of shearing speed was significant at 5% probability level. The shearing strength increased by increasing moisture content in all genotypes (Fig 2). Similar result was reported by Ince et al. 2007, Nazari Galedar et al. 2008 and Yilmaz et al. 2009 for sunflower stalk, alfalfa stem and sesame stalk.

![Graph](image2)

**Fig 2:** The effect of three genotypes of broomcorn (SHY, GAL and KAF), moisture content and stalk orientation (parallel (0°) orientation and (90° and 45°) orientations) on the shearing strength

**Shearing energy**
The shearing energy obtained by calculating the area under the curve of force deformation. The ANOVA results showed that the effects of moisture content and orientation were significant at 1% probability level. The amount of shearing energy increased when the cutting orientation changed from parallel (0°) to perpendicular (90°). And this amount increased by increasing moisture content, also Igathinathane et al. 2010 reported similar result for corn stalks, too.

![Shearing energy graphs](image1)

**Fig 3:** the effects of moisture content and orientation (parallel (0°) orientation and (90° and 45°) orientations) on the shearing energy of three genotypes of broomcorn stalk (SHY, GAL and KAF)

### Specific Shearing energy

The ANOVA result represented that the effects of genotype, moisture content, shearing speed and orientation were significant at 1% probability level. The amount of specific shearing energy increased by increasing moisture content also when the cutting orientation changed from parallel (0°) to perpendicular (90°). Chattopadhyay and Pandey 1999 reported that the amount of specific cutting energy decreased by increasing cutting speed and also they showed that the value of specific cutting energy was 35 \(kJ/m^2\).

![Specific shearing energy graphs](image2)
Fig 4: the effects of moisture content and orientation (parallel (0˚) orientation and (90˚ and 45˚) orientations) and Shearing speed on the specific shearing energy of three genotypes of broomcorn stalk (SHY, GAL and KAF)

References


