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Research Paper :

Force and energy required for cutting pigeonpea stems

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ABSTRACT

An attempt was made to investigate the cutting energy and force required for the pigeonpea stem at maturity of crops. The moisture content in the stem at the time of harvesting was 41.20% (w.b.). A blade, sharpened at 30^0bevel angle was attached to the lower end of the arm, which cut the stalk at 90^0 to the stalk axis with knife velocity ranging between 2.4 m/s to 6.6 m/s. The cutting energy and maximum cutting force were directly proportional to cross-sectional area of pigeonpea stem. The maximum energy and force observed to cut the stem of 30mm diameter were 141.90 Nm and 747.25 N, respectively.

Key words : Cutting energy, Force, Pendulum type dynamic tester, Velocity, moisture

The principle of operation of the cutting element employed in any harvesting tool or equipment can be broadly classified under two categories *viz.*, (i) cutting by impact and (ii) cutting by a counter-edge.

Two types of cutting mechanism, reciprocating type and rotary impact type, used for harvesting *viz.,* sorghum harvesting, forage harvesting, weeding, lawn mowing, etc. The latter is being increasingly used in these operations due to its simplicity in construction, low maintenance cost and ability to but both small and large diameter stalks. Effectiveness of impact cutting system as a viable alternative to the counter edge cutting is being progressively explored.

Cutting using single element differs greatly from that using two opposed elements. The latter case is cutting with counter-edge and thus, the stalk is supported in the vicinity of the cutting element. In this case, there is little or no energy wasted in the stalk deflection before cutting. Cutting with single element can be referred to as pure impact cutting and depends mainly on the knife speed, cutting edge sharpness and crop inertia. Stalk resistance to bending is insufficient by itself to provide the force necessary to oppose the knife pressure required to penetrate the material; the cutting process depends on the stalk inertia to give the required opposing force (Prasad and Gupta, 1975).

The energy required for the cutting unit of stalk cutter may be categorized as: friction in the moving parts of the machine and air friction; kinetic energy required to accelerate the chopped material; energy required to overcome friction of the chopped material against the stationary parts of machine; and energy required to cut the stalk (O'Dogherty *et al.,* 1995; Chattopadhyay and Pandey, 1999).

Despite the extensive studies conducted on properties of plants, stems and blade characteristics in relation to cutting performance (cutting energy) none was able to provide such comprehensive relationship for thick-stemmed crops as sorghum, millet, maize and pigeonpea.

Therefore, an attempt was made to investigate the cutting force and energy require for pigeonpea stems when they were subjected to impact cutting by pendulum type dynamic tester.

METHODOLOGY

A pendulum type dynamic tester was fabricated in the Department of Farm Power and Machinery, Dr. PDKV, Akola (M.S.). The dynamic tester is given in Fig.1. The line sketch (Fig. 2) shows the different forces acting on the blade edge and pivot point.

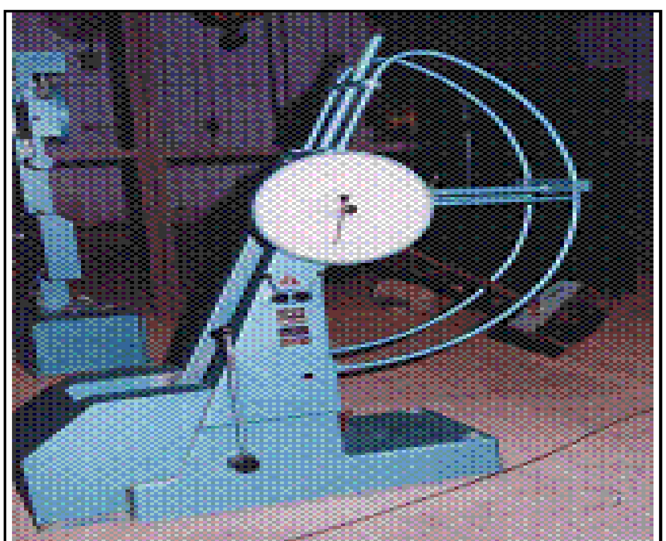

Fig. 1 : Pendulum type dynamic tester

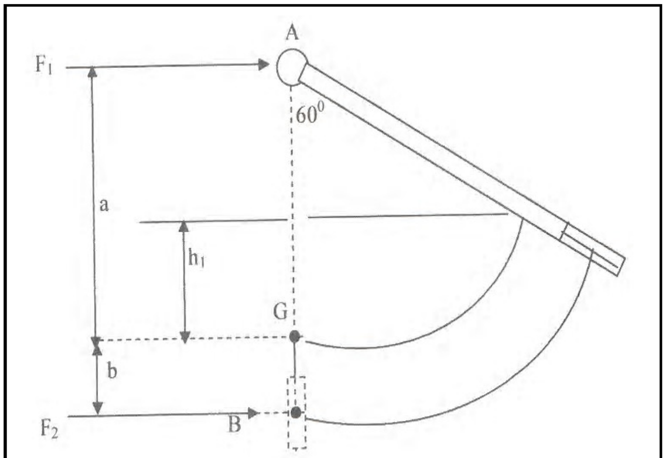

Fig. 2: Line sketch of pendulum type dynamic tester

Principle of operation:

A pigeonpea stem of selected diameter was first clamped in the vice. During experiment, a stalk was fitted in the vice to simulate natural stand of stalk in the field. Their average moisture content was noted. Angles θ_s and θ_1 were initially recorded by allowing the pendulum to swing freely before the crops were clamped in the vice. The pendulum was then subsequently released through the same angle and the clamped crops were severed. Angle θ_2 was recorded during the process of severing. Two replications of θ_2 were taken and the average value was then found out. Cutting energy was then measured by substituting the values of W, L, θ_2 and θ_1 in equation 1. The maximum blade velocity V corresponding to θs was then calculated from equation 2.

Pendulum type dynamic tester:

It consisted basically of a pendulum suspended on two ball bearings (UCS-204). It has a fixed hand vice for holding the stems. Cutting blade could be mounted on the tip of the pendulum. On the top there was a fixed circular aluminum plate graduated in degrees also called dial. A pointer actuated by a pin projecting from the upper arm of the pendulum showed the angle of swing of the pendulum on this graduated scale. The bench vice could be moved at right angle to the plane of the pendulum swing in order to vary the height of cut.

where,

F_1 and F_2- Force acting at pivot (A) and at cutting point of blade (B)

a- Distance between pivot point and centre of gravity

b- Distance between centre of gravity and cutting point of blade (B)

h_1- Distance between centre of gravity and centre of gravity of pendulum at releasing angle

The energy dissipated in cutting a specimen in given formula:

$$E = W L (\cos \theta_2 - \cos \theta_1) \text{ ———(1)}$$

where,

E = Energy dissipated, (kgm)

W = Weight of the swinging part, (kg)

L = Distance of centre of gravity of the swinging part from the pivot point of the pendulum, (metre)

θ_2= Maximum angle of deflection on the pendulum frame from vertical after cutting the specimen, (deg)

θ_1= Maximum angle of deflection of the pendulum from vertical at the end of free swing, (deg)

The maximum blade velocity at impact can be determined by nothing the angle of swing between the vertical and rest position. This is given by θ_s as shown in Fig. 2. When the pendulum weight W is released through an angle θ,

$$V = \sqrt{2gL (1-\cos \theta_s)} \text{ ————(2)}$$

The physical parameters like stem diameter, moisture contained, etc. of pigeonpea stems were measured.

Moisture content:

The moisture content of the pigeonpea stem was measured according to standard method. About 1.2 kg sample of stem was kept in an oven for 24 hours at 105^0 C. The loss in weight of the sample was recorded and the moisture content in per cent was determined as in equation

$$MC = (W_i \text{ x } W_d / W_i) \text{x}100$$

where,

MC = Moisture content, per cent

W_i = Initial weight, kg

W_d= Dried weight of sample, kg

RESULTS AND DISCUSSION

The three replications were taken for each diameter of pigeonpea stem. The dial showed the indicated angle for cutting pigeonpea stem of different diameter and corresponding cutting energy and force were calculated using for formula (Table 1).

In the experiment energy required to cut the stem of the pigeonpea was minimum for 8 mm diameter 17.38 Nm and maximum for 30 mm diameter 141.96 Nm, whereas cutting force for the stem diameter 8 mm was 232.5 N and for stem 30 mm it was found 747.25 N.

It showed that the cutting energy and force required for cutting pigeonpea stems increased gradually as the

Table 1 : Cutting energy and force required for cutting the pigeon pea stem

Pendulum dropped at an angle, degree	Stem diameter (mm)	Indicated angle (degree)		Cutting energy (Nm)	Cutting force (N)
		Swing of arm from pivot with cutting angle (degree)	Swing of arm from pivot without cutting angle (degree)		
30	8	8	24	17.38	232.50
40	12	12	32	29.48	296.80
55	18	15	41	47.86	337.75
70	24	13	58	100.72	709.00
90	30	10	69	141.96	747.25

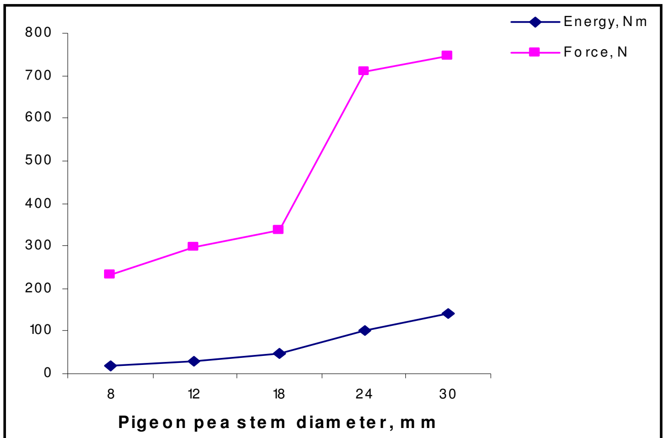

Fig. 3 : Cutting energy and force for pigeon pea stem

diameter of the stem increased from 8 mm to 18 mm. But energy and force suddenly increased from stem diameter 18 mm to 24 mm (Fig.3). It may due to full maturity of plants. Full mature plants cellulose became compact and hard so the force required to cut was increased as diameter increased.

Conclusions:

The following conclusions were obtained from the experiment

– Knife speed ranging between 2.4 m/s to 6.6 m/s for cutting the pigeonpea stem of diameter ranging from 8 mm to 30 mm, respectively.

– The energy and force required to cut the pigeonpea stem increased from 17.38Nm to 141.96 Nm and 232.50N to 747.25N with increase in cross sectional area of stem, respectively.

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